FACTORY MANAGEMENT COURSE AND SERVICE

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STAFF.

TOOLS AND PATTERNS

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PREFACE.

Many factory executives are chiefly concerned with the commercial end of their business, and yet do not possess the technical training to enable them to judge of the relative value of the methods of production used in their own factory. In this they are at a decided disadvantage. Others, however, do attempt to obtain a technical training while engaged in the management of their plant, and profit largely thereby. A thorough training along mechanical lines may not be necessary, but it is an excellent thing for the executive to familiarize himself at least with the fundamental principles underlying mechanical work.

Tool equipment needed to produce a given piece of work need not be understood in detail, but the executive should know the difference between a boring bar and a milling cutter, for instance, and should understand something of the reasons why one type of tool is more suited to the work in hand than another. He should also know what reasons there are for planing a piece of work instead of milling it; or boring and reaming instead of drilling. He should know what class of work requires fitting of such a character that the surfaces must be scraped in order to produce a proper bearing. He should understand something about the various machining processes, and also something about grinding. When a turning operation is indicated and when a surface needs to be ground to secure accuracy are all essential points regarding which a progressive executive should be posted. In addition to these, the production of interchangeable work should be grasped in its fundamentals. He should further know the possibilities of gauging work to produce it with a minimum

of expense and within the required limits of accuracy consistent with the commercial quality of the product. If the executive does not understand something of these details he must depend entirely on his subordinates for information.

In order to assist the progressive man and to enable him to secure concise data on tool equipment in a single volume, this book has been written and arranged. The intention of this treatise has been to take up the points mentioned in such a way that a non-technical man can readily grasp the fundamental principles underlying the matters pertaining to tool equipment. It is the belief of the author that executives will find themselves vastly benefited in their work by a careful study of its contents; for it is evident that the man who knows the essential principles underlying the design and upkeep of his tool equipment will be much more likely to obtain maximum efficiency in his product than another who is not so well posted.

ALBERT A. DOWD.

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TOOLS AND PATTERNS

CHAPTER I

HAND AND FORGED TOOLS

The Details of Manufacturing.—Any machine tool in itself is of little practical use unless furnished with suitable cutting tools. So also any factory is incomplete unless the shop equipment is efficient and the methods of handling the work are in accord with the most modern practice. The manufacturer who neglects these vital points and overlooks the many details connected with his work, or who is satisfied with antiquated methods and equipment will eventually find himself distanced in the race of progress by his more up-to-date competitors. Recent developments in tool equipment and modern methods of handling are so far in advance of older methods of treatment that it is imperative for a successful manufacturer to study the details of his equipment more carefully, so that his own judgment will enable him to stop the leaks which may be responsible for losses in production and to apply new principles which will bring his efficiency up to the maximum.

The purpose of this book, then, is so to instruct the progressive executive in the various details upon which his success depends that he may be able to

judge intelligently of his shop equipment, to develop his methods of handling along the most approved mechanical lines, and to control economically his entire organization. In order to treat so extensive a subject logically, it will be necessary to separate it into several broad divisions, each of which may be again divided as seems desirable.

Manufacturing Conditions.—In any factory the methods of handling work and the equipment most suitable for particular cases are largely dependent upon the product that is to be manufactured. The quantity produced is a very important factor, for it is obvious that methods can be developed to produce interchangeable work on a large scale when there is little likelihood of a change in design, and yet these same methods might not prove economical where the production was small and when there is a strong possibility of a change in design from time to time. Methods of handling, tool equipment, special machines, and many other details must be planned in accordance with the work to be done. Now while the small manufacturer can not bring into use the many labor saving devices of the big producer, he can nevertheless profit by the other man's experience and can develop similar processes, frequently, suitable to his own work but on a smaller scale. It is therefore of the highest importance that he should become familiar with the best methods of manufacture as they have been developed by progressive people, and that he should study the application of principles to determine how far they may be applied to his own work.

Many instances are seen where a small manufacturer runs along "in the same old rut" year after year and even makes a comfortable income for a time, until at last his dwindling profits show him that something is radically wrong and that he must look into some of the details of manufacture more closely or be content with a much smaller profit than formerly. Evidently a condition of this kind does not develop at once; it is a gradual process and therefore is much harder to combat. When such a condition first becomes apparent, a course of treatment is necessary in order to prevent further losses. In actual practice, though, it is difficult for a manufacturer to realize that he is losing ground, because it seems to him that he is continuing along the same lines that he has followed with success for a number of years.

This state of affairs may be likened to a slow process of decay or a lingering disease which becomes chronic after a considerable period of time. The best of all remedies for a disease of this kind is knowledge. As the manufacturing world progresses, and as new methods are developed and applied, the executive must keep pace with his competitors and profit by their experience as far as possible.

Interchangeable Manufacture.—Strictly speaking the process of interchangeable manufacture is applicable only to high production work when a great number of parts of the same kind are to be manufactured. When parts are truly interchangeable any one part can be used in the place of another without the necessity for hand fitting. In an automobile, for

example, a broken part can be replaced with a new one with the assurance that the new part will fit as well as the old. Theoretically an entire machine can be built by the interchangeable system in such a way that all the parts can be assembled to make a perfect whole without the need of any fitting. Practically, however, there may be a few parts that must be "touched up" with a file here or there, or there may be a hole drilled at assembly in order to complete the mechanism. But it is an accepted fact that by the greatest care in manufacturing and by a proper system of gauging and inspection, hand fitting and machining operations at the time of assembling can be done away with entirely.

When any product is to be manufactured on the interchangeable system, the gauging of the various components and the system of inspection are of supreme importance. The various parts which go to make up the completed product must be manufactured in such a way that there will be no more variation in size than the nature of the mechanism will permit, and this variation must be held within carefully fixed limits. For this purpose gauges must be made such that they can not be applied to the work if the variation is too great.

By means of limit plug gauges for the inspection of holes and limit snap gauges for outside dimensions any number of male pieces can be made to fit corresponding female pieces in the desired manner. Shoulder distances, flanges, contours of irregular parts, and many other kinds of fits can be held within the desired limits of accuracy by a proper system of

gauging. The matter of allowances for fits of various kinds must be most carefully worked out according to the nature of the product to be manufactured. Thus, the allowances made for running fits in a piece of farming machinery would be much greater than in a high-grade automobile, and yet the parts would be interchangeable in the one case as well as in the other.

Tool Equipment.—The tool equipment for any factory may be divided into two broad groups, perishable tools and permanent tools. For purposes connected with cost finding these groups can be separated by a more or less flexible line, but from the mechanical standpoint this grouping is by no means specific enough and can not, therefore, be followed out logically without causing more or less confusion. For example, it is evident that files or hacksaws are perishable tools, because they wear out in use and can only be replaced by new ones as they cannot be re-sharpened. On the other hand, jigs and fixtures, surface plates, and other tools of like character may be classed as permanent tools because their lives are very long and they can be maintained and put in good condition at a nominal cost, unless of course they are accidentally broken. As this book deals with the mechanical aspect of the tool situation rather than the cost finding end of it, I shall consider the mechanical viewpoint in this discussion, keeping in mind and giving due consideration, however, to the matter of upkeep in specific cases.

It is doubtless better to consider tools from the standpoint of the work which they do than in any

other way, although the machine on which the tools are used will also have a certain effect on the grouping. For example, a drill is used for drilling a hole and it is frequently used on a drilling machine or drill press. So also a turning tool is used for turning, a recessing tool for recessing, a threading tool for threading, a reamer for reaming, and a file for filing. It can readily be seen, then, that the cutting operation on the work has a positive effect on the name of the tool. Some tools which will be described herein, are not used in machines but are hand tools, such as files, scrapers, cold chisels and the like. Other tools, again, such as surface plates, vises, and so on, can be readily grouped under shop equipment. Tools such as chucks, face plates, tool holders, etc., form a part of the machine equipment, and are therefore classed in this way. Other tools are grouped according to the kind of work for which they are intended or by the machine on which they are to be used.

Any factory depends for its success upon the efficiency of its tool equipment, and it is therefore of the highest importance that these tools should be so well designed, carefully made, and maintained that no loss of production can ever be laid to their inefficiency. In discussing the purposes and application of tool equipment and kindred subjects treated here, cases will be cited which are for a large part fundamental in their application. Complicated design and intricate mechanisms will not be considered. The executive, who may not be a strictly mechanical man, will find that the principles involved and the instances noted are well within his mechanical scope.

The superintendent or foreman may discover that mechanical features are treated in such a way as to bring out many new points of interest. The shopman and mechanic will appreciate many practical examples which are given; and the designer may profit largely by his technical knowledge which will give him a more intimate understanding of many interesting points in design treated, perhaps, in an entirely new way.

Classification of Hand and Forged Tools.—Files, cold chisels, and scrapers are essentially hand tools. Hacksaws also come under this grouping, although they are often driven by power for cutting off stock from bars. Forged tools are used in so many forms and shapes and for so many purposes that their grouping is a difficult proposition. On this account I have included them in a separate group in this chapter, regardless of their shape or form or the class of machine they are to be used with. But because there are so many shapes of forged tools, the subject will be treated broadly, with a few general hints on the theory of cutting, the proper angles of the tool, and so on.

In the descriptions in this volume of the various tools I have aimed to give principles and points of particular value, but I have made no attempt to cite every variety of tool. Rather my purpose has been to give a broad general classification which will be of the greatest value without too technical a treatment. Important points in connection with upkeep and economy of operation will be noted from time to time.

Files.—In general there are three classes of files in common use, their classification being dependent upon the kind of cuts which form the teeth. The three classes are rasps, single cut, and double cut. The types or classes are graded according to length and fineness of the teeth and are specified as rough, coarse, bastard, second cut, smooth, and dead smooth. The lengths of the various files are from four to sixteen inches, and each length of each class has its own grade determined by the number of teeth to the inch (or "pitch," as it is sometimes called). The fineness of the teeth being proportional to the length of the file it is evident that the term second cut, for example, does not indicate the size of the teeth unless the length of the file is also known.

Files are of numerous forms to suit various kinds of work, the flat, half round, round or "rat-tail," triangular, and square forms being most commonly used. Files of these varieties are full tapered or tapered in both thickness and width for about two-thirds of their length, the remaining third having nearly parallel edges. A warding file tapers in width but not in thickness, while pillar and hand files taper in thickness but have parallel edges. Saw files and equaling files are nearly of the same size for their entire length. The tang of a file is the part to which the handle is fitted and the heel is the part next to the tang. When one edge of a file is smooth it is termed a "safe" edge. The various methods of cutting file teeth are shown in Figure 1 together with several cross-sectional forms.

Since files are used for a great variety of work in

any factory their cost becomes an item of considerable importance. It behooves an executive to see not only that the files ordered are of the proper grades, but that they are used as they should be and for the work for which they are intended. It is evident, therefore, that the selection of a file for a given piece of work is worthy of a certain amount of attention. For example, in selecting files for any work it is necessary

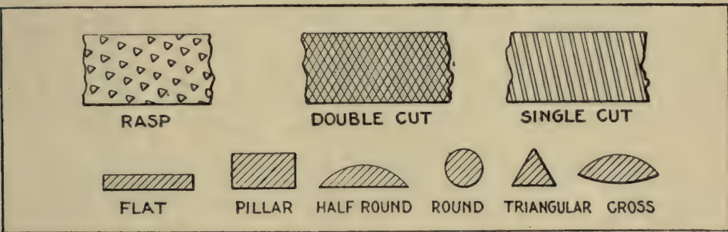

FIG. 1. FILE FORMS AND CLASSES

to know the kind of metal to be cut, whether the surface to be worked is broad or narrow, whether the metal is wrought or cast, and whether it is to be smooth or draw-filed or will be finished in some other way. A rough-cut or coarse file would be used on a broad surface if much metal is to be removed, and a new file would be used rather than an old one if the material is a casting. A file which has been somewhat worn can be used on wrought work to advantage, but it would not give good results on a casting. In general, thin files are to be avoided, except in the hands of a skillful workman, for they are very apt to produce a rounded surface.

In filing wrought metals a little oil or turpentine may be used on the face of the file so that the file

will "take hold" better, but cast metals should always be cut dry. Chalk rubbed on the file teeth when filing castings will prevent clogging, and the use of a file card (a wire brush for cleaning the teeth) cannot be too strongly recommended. When a file becomes clogged the depth of the cut is reduced and slower work is the outcome; and on wrought metals chips will pack into the file teeth and scratch the work unless the file is kept clean. Again, many files are ruined by being used on the scale of a casting; the edge of the file only should be used to get below the scale and then the flat side can be used to advantage without injury to the teeth. Proper care of a file consists in careful handling, suitable selection, and a thorough cleaning. When oil or turpentine has been used on a file, it can be given several applications of chalk which will absorb the moisture and bring out the chips between the teeth, so that it will be clean and ready for the next job of work.

Hacksaws.—Hacksaws are of two varieties, those used in hand-saw frames and those used on power-operated sawing machines. A number of years ago hacksaw teeth were punched, but at present this method is little used and the teeth are now milled. The hacksaw blade used in hand hacksaw frames is little different from the machine saw blade except that it lighter and not adapted to such heavy service. The teeth of hacksaws are "set" in different ways to suit different cutting requirements, and the practice of various manufacturers differs somewhat in this regard. For example, considering the teeth as set over an each side of an imaginary center line, one

maufacturer may make a saw blade with every alternate tooth set out from each side of the line; another may be made with two teeth set out the same distance from the center line and an intermediate tooth on the center line; a third variety may have two teeth on one side, one tooth on the center and then two teeth on the other side; while still another may have one tooth set out a certain distance on one side of the center line, the next tooth set out the same distance on the other side of the center line, then two teeth set out not quite as far on each side of the center line and a fifth tooth set on center. These variations in the setting of the teeth are not followed to any great degree by different manufacturers, although certain claims in regard to their value for different classes of materials may have considerable value.

Ordinarily hacksaw blades have one tooth set to the right, the next to the left, and the third one on the center line. The teeth which are set out from the center widen and deepen the cut of the saw, while the straight teeth in the center tend to keep the cut free from chips. The tooth spacings commonly used vary from nine teeth to the inch to thirty-two teeth to the inch. Speaking generally, saws having the coarser spacing should be used on soft materials, such as wood, fibre, or soft metal. The finer spacings are better for hard metal, because they are less likely to "strip." For the average work in the machine shop for hand work blades having eighteen teeth to the inch are recommended, while for machine work blades with twelve to fourteen teeth to the inch are most

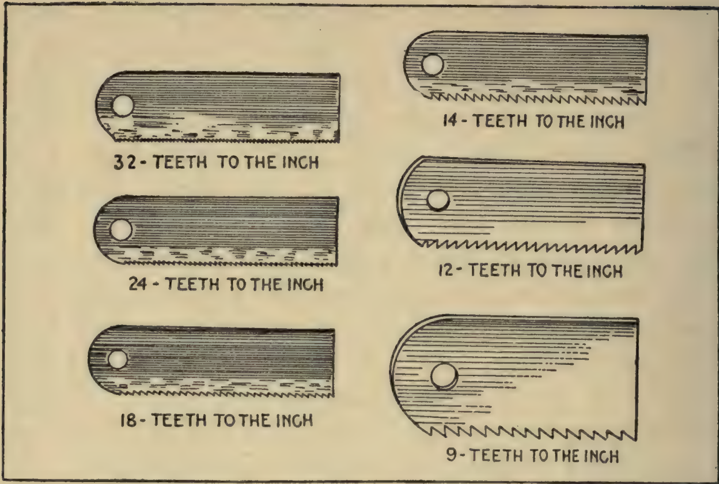

FIG. 2. TOOTH SPACING IN HACK-SAW BLADES
(Slightly Reduced)

economical. A comparison of the tooth spacings will be found in Figure 2.

To obtain the best results in using hacksaws, whether for machine or hand work, the blade should be well strained in the frame to insure true cutting and to prevent breakage. The selection of the proper saw blade for a given class of work makes a great difference in the efficiency obtained.

Cold Chisels.—Cold chisels are made in many forms and for various classes of work, such as chipping, key-seating, oil-grooving, cornering, and prick-punching for correcting errors in drilling and also for laying out work to be machined. When castings are received from the foundry, often they will be found with ragged edges or other inequalities which, unless removed before machining, would interfere with their

handling. Several methods are used to smooth up the surfaces; small castings are "snagged" on a coarse grinding wheel which is mounted on a spindle in a heavy floor stand; larger work is roughed off with a smaller wheel, one that may be operated by a flexible shaft suitably counterbalanced to facilitate handling or mounted on a small truck and operated by an electric motor. Or large work may be chipped with a cold chisel, usually one operated by compressed air in a chipping hammer, or by hand in some cases. Compressed-air chipping hammers are very rapid in their action and can be made to cover a considerable amount of surface in a remarkably short time. Hand-chipping operations are much slower but can be used for purposes not adapted to machine chipping.

A number of forms of cold chisels are shown in Figure 3. The tool, A, is known as a flat chisel; B, a cape chisel; C, a round nose chisel or gouge; D, the cow-mouth; E, diamond point, and F, a straight-side chisel. An important point in connection with cold chisels is the angle of the edges in relation to the cutting point, as these edges serve as guides in chipping operations. Figure 4 shows, at A and B, the manner in which these edges act as guides when work is being done. Taking the flat chisel as an example and referring to the diagram shown in Figure 4, it will be seen that the angle of the edge, as indicated at A, tends to shear the metal on the upper side and acts as a guide on the lower surface of the chisel to prevent too deep cutting. In the example B, the tool has been ground incorrectly, so that there is no shearing action on the metal and the tendency is for the

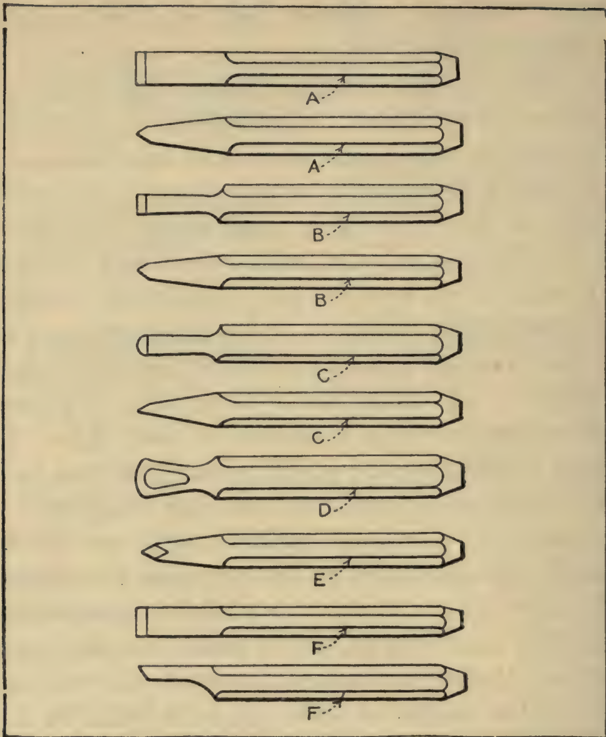

FIG. 3. DIFFERENT FORMS OF COLD CHISELS

chisel to gouge down into the work and not produce a good cutting action.

The cape chisel, B, in Figure 3, is made so that the point is narrow and tappers back slightly to give clearance when cutting a key way or something of this kind. This clearance also prevents upsetting the metal and raising a burr along the edges of the groove. So also the gouge, C, has a slight amount of back clearance to facilitate the cutting action. This type of

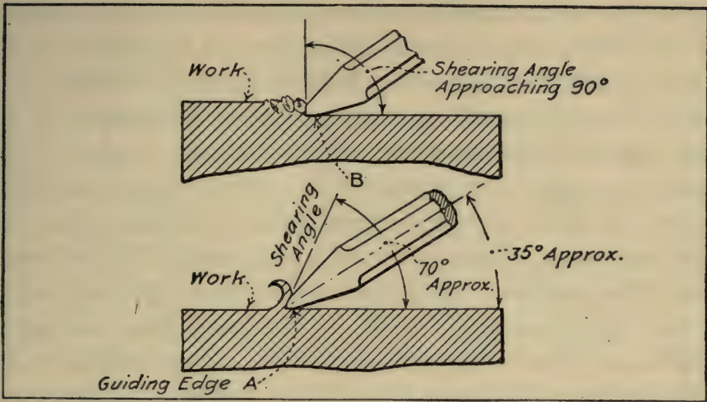

FIG. 4. EFFECT FROM INCORRECT AND CORRECT ANGLES ON COLD CHISELS

chisel is used largely for cutting oil grooves in bearings, pulleys, and similar work. It will be seen that this type of chisel is ground at a different angle than the cape and flat chisels. This is done so as to permit the operator to change the depth of the cut by raising the end of the chisel a trifle while in use. The cow-mouth chisel is used for chipping circular work; while the diamond point, shown at E, is used for correcting errors when drilling holes, for chipping in the corners of dies, and such work. The straight-side chisel, shown at F, is commonly used by die makers for squaring up the sides of punches and dies and for squaring out holes, cutting shoulders, and the like.

Scrapers.—After a piece of work has been machined, the eye is deceived into thinking that the resulting plane surface is smooth and free from humps and hollows. As a matter of fact, however,

the apparently smooth surface is much like the waves of the ocean on a small scale; hence, if it is necessary to have a perfectly fitting piece of work, the "high spots" must be removed and the whole surface worked down more nearly level. These high spots can only be levelled by hand with scraping tools. It may seem strange to the layman that a piece of work, if properly clamped, cannot be finished to a true surface on a high class machine tool, and if the machine tool itself is in first class working condition, but even under the most favorable conditions there is bound to be a certain amount of "spring" both in the work being machined and in the tool which is cutting it. Hence, work which has been machined shows an infinite number of high and low spots more or less evenly distributed over the surface. If two moving parts were to be fitted together with these high and low spots still upon them, it would only be a short time before the wearing down of the spots would destroy the alignment of the pieces, seriously impairing their accuracy. As an example, consider the "ways" of a planer or of a turret lathe: In the planer, if the ways were not scraped to a perfect bearing one side would be very apt to wear more than the other, so that the work produced would not be accurate—it might be tapering, convex, concave, or even a combination of all inaccuracies mentioned. In the case of the turret lathe, the center of the turret would not line with the spindle after a short while, and the holes bored and surfaces turned would be tapering or otherwise distorted.

It will be seen from the foregoing that on flat work it is necessary to scrape all surfaces which are to be in moving contact with other flat surfaces. When their contact is with cylindrical bearings, they may be scraped, lapped, or ground according to the particular requirements. The art of scraping requires practice, a nice sense of touch, and a considerable amount of judgment. Many people not conversant with the necessity of scraping bearing surfaces, imagine that the mottled effect produced is for ornamental purposes, yet it is highly essential on any well-made machine and serves no other purpose than that mentioned.

Many varieties of scrapers have been designed simply to fulfill a need for a tool to get at some particular piece of work of unusual form on which a bearing was desired. In Figure 5 is shown a double-end scraper, A, commonly used on plane surfaces and broad work. It will be seen that this type has a broad flat surface and is perfectly square across the end. Such scrapers are often made single-ended from an old file, having a wooden handle on one end; but for heavy work the double-end tool shown is to be preferred, for it is not likely to spring and its weight gives an added advantage. It is important that any scraper of this type should be ground perfectly square across the end so that it will not tend to gouge work when in use.

Scrapers are hardened to as high a degree as fire and water and the metal itself will permit. The scraper, B, in Figure 5 is hook shaped, which permits it to be pulled toward the workman instead of pushed away

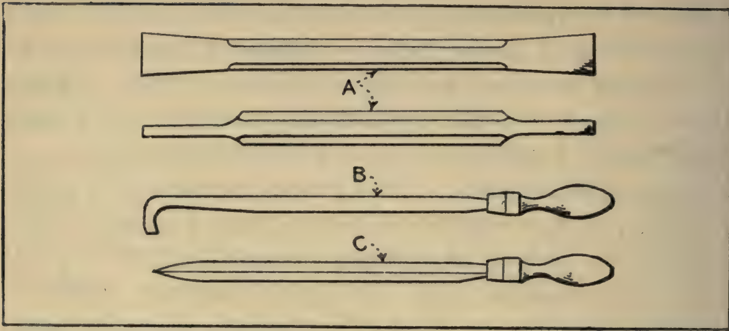

FIG. 5. VARIOUS TYPES OF SCRAPERS

from him, as in the case of the double-end scraper. The triangular form, C, is sometimes made from a three cornered file from which the teeth have been ground away. All scrapers are made of high-grade steel, as the service to which they are put is so severe that no economy would be found in using low-grade steel for the purpose. Scrapers of the three-cornered variety are largely used for scraping bearings of cylindrical form, such as the crank-shaft bearings in an automobile, or spindle bearings in machine tools.

When flat surfaces are to be scraped, a "master" or standard surface plate is used and the parts to be fitted are rubbed on it to determine the high spots. In using this master plate a very light coating of Prussian blue, red lead, or lamp black is spread upon the machined work which is then rubbed upon the master plate; the high spots on the machined piece show bright and are removed with the scraper. This performance is repeated until the work shows an even bearing all over. When completed a series of high-point bearing spots very close together is ob-

tained all over the work, so that it has the mottled appearance previously mentioned.

Forged Tools.—All varieties of work on nearly every class of machine tool require the use of forged tools. Many shapes and forms are adopted, depending on the work for which they are intended. Generally speaking, their construction is such that they can be ground several times before reforging is necessary. On lathes and planers they are used to a greater extent than on any other classes of machines, and many tools of the same general type can be used on these two machines.

A group of lathe and planer tools, which may be considered as representative types is shown in Figure 6, although many modifications are required to suit particular cases. It is unnecessary to take up each of the tools illustrated and describe its functions, for the reason that tools of this kind are so well known that they require little description and can be found

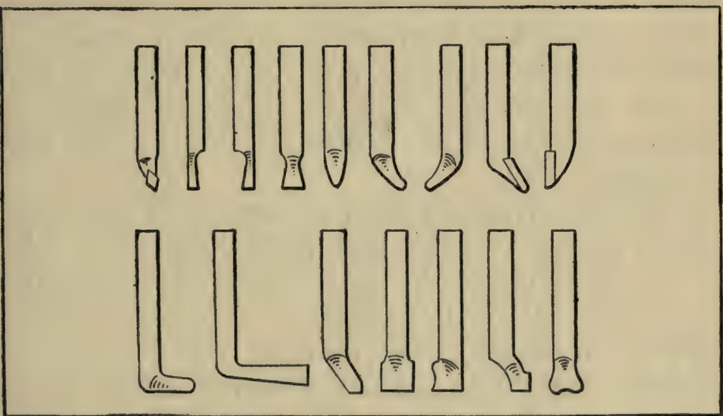

FIG. 6. A GROUP OF FORGED TOOLS

in every modern factory as well as in those of older days.

The matter of upkeep of cutting tools, however, is a subject which should receive most careful attention; and as the upkeep and productive capacity of any tool is dependent upon its shape we will consider the points which are important in regard to cutting angles and shapes of the several varieties of tools.

It is evident that any kind of cutting tool, to produce its maximum amount of work, should be so shaped and ground that it will remove the metal with the least possible amount of friction. When such a condition is reached the machine tool is at its best, and the work is produced with a minimum amount of labor. Further than this, the life of the tool is prolonged because the periods of regrinding are lessened.

The simplest types of tools are used on planer work, for the reason that the cutting action of the planer is along a straight line. On the other hand, a lathe tool is also used on the outside of cylindrical work, in boring a hole, or in turning a taper, so that in each case the tool must be differently shaped in order to clear itself and "turn the chip" to the best advantage.

A number of factors must be considered in the design of cutting tools, such as the position of the tool in relation to the work, the spring of the tool under the cutting action, the shape of the work, and the material to be cut. For example, soft and fibrous materials require an entirely different cutting angle than do materials having a short-grained structure.

The tool, A, shown in Figure 7, is seen to be improperly designed for planer work, because an excess of power is required to pull the tool and, furthermore, it really does not cut at all but crowds or pushes the metal off. If such a tool were used for a long while under the condition shown it would in

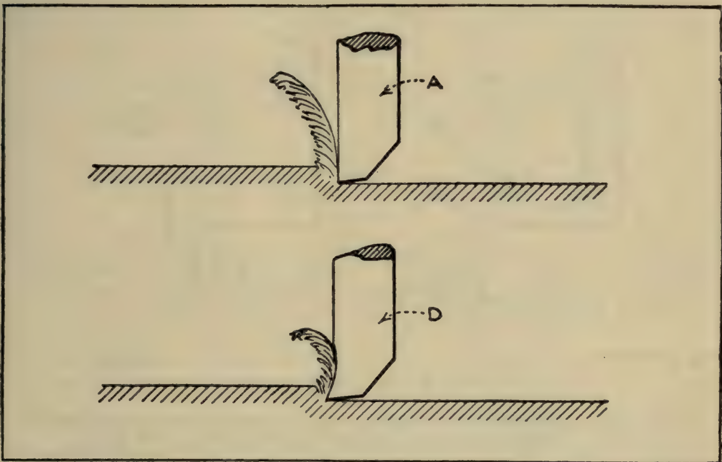

FIG. 7. THE CUTTING ACTION OF PLANER TOOLS
(A) Incorrect Form of Cutting Tool. (D) Abrasive Action of Chips on Face of Tool.

time develop a form similar to that shown at D in the illustration, because of the abrasive action of the chips against the tool. It would be perfectly logical to assume, then, that if the tool were ground to this shape in the first place its form would be more nearly correct.

The manner in which any cutting tool is supported determines to a certain extent its shape, because the spring of the tool holder may tend to carry it into

the work and produce "chatter." An example of this kind is illustrated in the planer tool, A, Figure 8. As the work moves in the direction indicated by the arrow, the tool and tool block together will spring (if sufficient pressure is applied), radially from the corner B with a tendency to dig into the work.

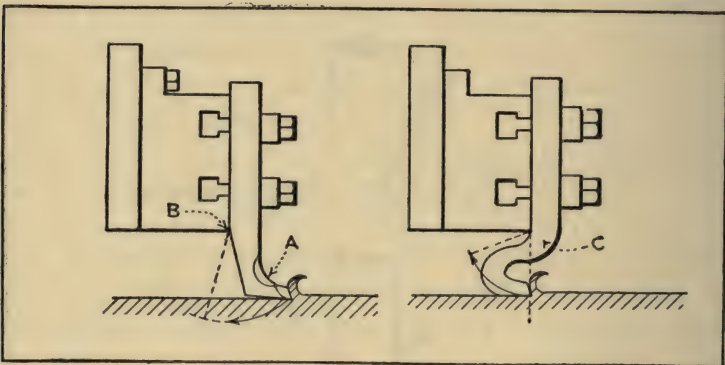

FIG. 8. PLANER TOOLS

(A) The Digging Tendency of Tools Productive of Chatter.
(C) Tool Springs Away from Work and Does Not Dig in.

For this reason the tool may be made as shown at C, with the cutting point far enough back so that any spring action will carry the tool away from the work, thus obviating "chatter." The heel angle of a cutting tool should be of such shape as to resist the cutting strain to the best advantage. It is obvious, therefore, that heavy cutting tools, such as those used on a planer, should have a greater body of metal and less clearance behind the cutting edge than those used for a lighter class of work.

The diamond-point tool, shown in Figure 9, is a common type of lathe tool, but such a tool is limited

in its productive capacity by the width of the cutting face and the strength of the neck. It is not suited to high-speed work nor to fine finishing, except on wiry material such as tool steel or alloy steels. In work of this nature it may be used for finishing, providing that a very fine feed is given

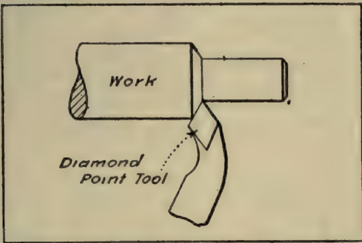

FIG. 9. DIAMOND-POINT LATHE TOOL

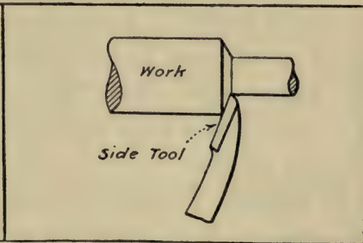

FIG. 10. SIDE TOOL FOR ROUGHING DOWN WORK

the machine tool and a slight "drag" is stoned just behind the cutting point so as to produce a burnishing effect on the work. Many mechanics use a side tool such as that shown in Figure 10 for roughing-down bar stock, for the cutting face of the tool is wide and it can be made to take a very wide chip if set as indicated in the illustration.

In addition to the points above mentioned, when a cutting tool is to be used on cylindrical surfaces, as in the case of a lathe job, the position of the tool relative to the center of the work is of importance. Theoretically a tool should be "on center," whether it is boring a hole or turning an outside cylindrical surface. It must be remembered, however, that the majority of tools are more or less elastic and will show a certain amount of spring which must be taken

into consideration in setting the tool. Hence, if an outside diameter is to be turned, for example, the tool should be set slightly below center so that it will not dig in under the pressure of the cut but will rather tend to spring away from the work. Similarly, in boring a hole the tool should be slightly above center so that its spring under the cutting action will also carry it away from the work. But as previously mentioned these points will depend entirely upon the manner in which the tools are supported and upon the direction which their deflection will take under the cutting strain.

Grinding Tools.—In past years it has been the custom for mechanics to grind their own tools to any particular kind of a shape that they fancied gave the best results. The natural consequence of a procedure like this was that one man's work would be much superior to another's because of a greater knowledge of tool shaping. At present, however, it is possible to purchase a tool grinder for forged tools so that all tools of any particular variety can be ground to a predetermined angle, even by an inexperienced man. The work produced with tools uniformly ground is much superior to that done by a "hit or miss" method, and the life of the tool is correspondingly prolonged. In addition, the amount of time lost in regrinding tools is greatly reduced and the labor of a skilled mechanic is not required. In determining proper angles for cutting tools the aim should be toward the ideal form which will turn the chip to the best advantage with the least amount of power and at the same time to give the longest life to the tool.

Especial caution should be exercised not to obtain an angle so sharp that the cutting edge will approach the wood tool in shape, for a tool with such an edge would have a very short life and would require frequent regrinding.

Tools for Holders.—In order to economize in the amount of high-speed steel used in forged tools a number of holders have been devised which require only small sections of such steel. These holders are so arranged that they will take stock of standard sizes and clamp them securely; in this manner they will answer many purposes of forged tools made from high-speed steel. or certain clesses of work they are extremely valuable; but for very heavy cutting forged tools are still preferred in many factories because the heavy forged tools have a greater section and carry away the heat more rapidly than the smaller sections used in holders, and are therefore capable of higher speeds and greater production. This fact, however, does not detract in any way from the utility and economy of the holders mentioned. These holders will be described in more specific detail in the discussion of tool holders.

CHAPTER II

DROP FORGING AND BLANKING DIES

Principles of Drop Forging.—Although drop forging dies may be re-cut when they become greatly worn, they should still be considered as perishable tools; a great deal depends upon the treatment of the die, both in the process of hardening and also in its use. The construction and form of the die itself makes a great difference in its life, and it is difficult to estimate the number of pieces upon which any die can be used on account of the variations in the form of pieces to be drop forged. When a comparatively small number of pieces are to be made, it is possible to make up cast iron dies, but of course these are not serviceable for any length of time. When only six or eight similar pieces are to be made cast iron dies are most economical. But in work requiring a large production the dies are made of steel containing from 0.45 to 0.60 per cent carbon, and the blocks from which they are cut range between 5 and 8 inches in thickness. Usually the dies are dovetailed, as shown in Figure 11, to fit the drop hammer in which they are to be used.

Since the advent of the automobile, drop forging processes have been greatly perfected, and many forgings are now made which would have been con-

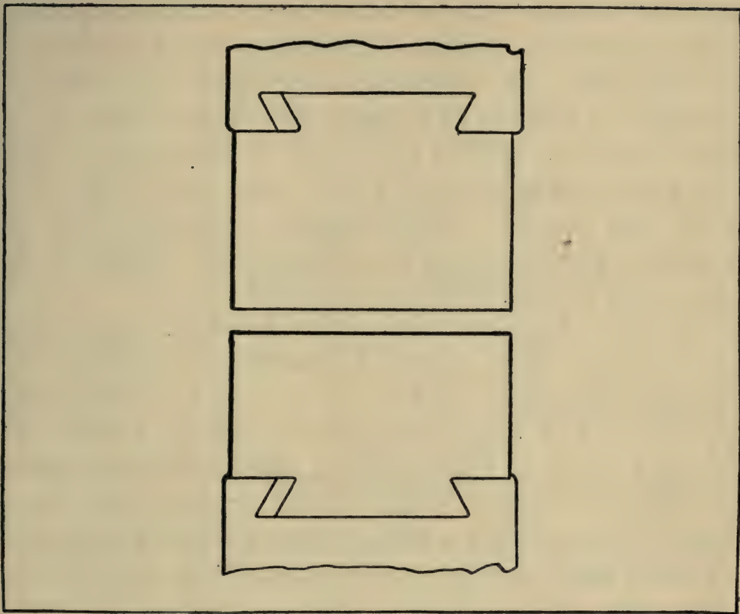

FIG. 11. DOVE-TAILED DROP FORGE DIES

sidered impracticable a few years ago. The necessity for extraordinary strength in certain parts has led to the adoption of alloy steels for these pieces and drop forgings are made to suit the conditions.

Comparatively few pieces of work have a form such that they can be produced in a single pair of dies. When the diameters do not vary greatly in the different sections, circular forms can be made in a single set of dies; but forms of widely varying section require a preliminary "breaking down" operation, and when a heavy boss is a part of the forging three or four operations may be necessary before the piece is completed. When the forgings are small,

several recesses can be made in one set of dies for breaking down, formation, cutting off, and nicking for breaking off. Generally speaking, it is best to complete a forging at a single heat if possible, but in some instances several heats may be necessary. When work is of large size and two or more sets of dies are used, the hammers can be placed near each other, so that the workman can step immediately from one to the other without "losing the heat."

In work done on the anvil by hand the smith acts as an artist and models his work to the form required, drawing it out here or there as the design may call for. But when forgings are made in dies, the amount of metal from which a piece is stamped must be large enough so that it will overrun the die a trifle, thus assuring a full die and a forging of proper shape. The "fin" which is squeezed out between the dies at the time of forging must be removed by means of trimming dies. Provision is made in the dies themselves to take care of this fin, as shown in Figure 12. A wide and rather shallow groove which is cut all around to receive the fin is shown at A, and the manner in which the faces of the dies are sometimes sloped away for the same purpose is shown at B. Figure 13 shows a forging of a lever which has the fin, X, still on it, and the trimming die, shown in the lower part of illustration, shears off the fin and leaves the forging clean and ready for use.

Cylindrical work can be manipulated by the operator so that no fin will be left by simply rotating the work under the hammer during the process of forging. Drop-forged levers are frequently made with a

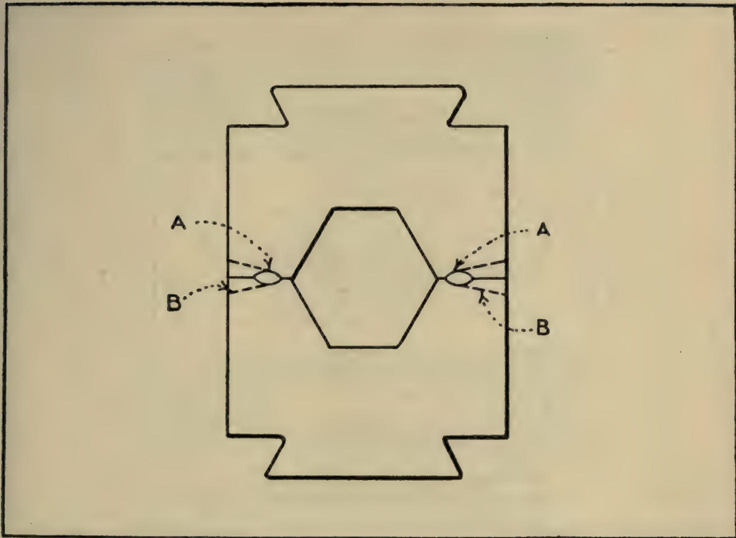

FIG. 12. DROP FORGE DIE WITH SPACE FOR RECEIVING FINS

countersunk portion in the center of the bosses in order to facilitate machining, as shown in "A" of Figure 14. Other cases when the hole itself can be punched directly through the work are indicated in the dies shown at "B" in the same illustration. Occasionally the hole in the boss is taken care of by the method shown at "C"; this leaves a thin web at the center of the hole, which is afterwards punched out without difficulty. So many forms of dies and forgings for all classes of work occur that it is obviously out of the question to do more than outline the simple form so as to give an approximation of the method of treatment.

Blanking Dies.—When work is produced from cold metal the processes used for shaping the forms are

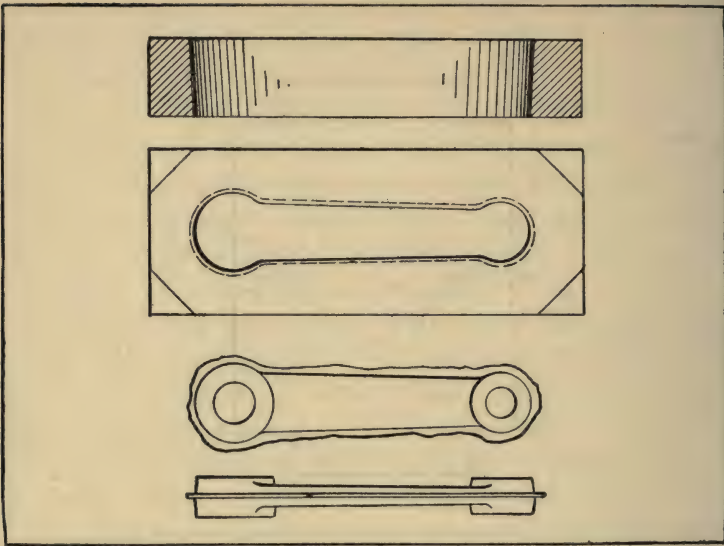

FIG. 13. A ROUGH FORGING AND ITS TRIMMING DIE

very different from those previously described under the head of drop forgings. Cutting dies should properly include all types which punch or cut out various shapes from the metal as it is fed through the press when the section of the metal itself is not changed to any extent. Shaping dies on the contrary include any which change the form of the metal from its original flat condition to one of a different contour in which the various surfaces are in different planes. Some dies of the latter class really constitute a combination of cutting and shaping dies—the work is first punched out to shape and is afterwards formed.

Follow dies are dies which have two or more cutting portions acting progressively on the work as it

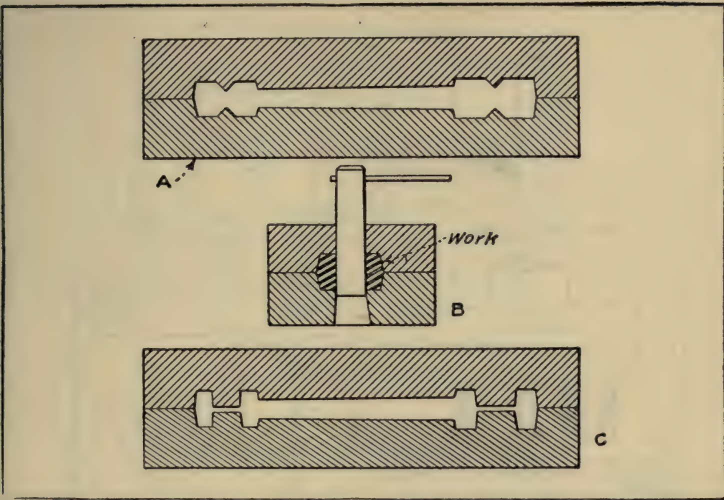

FIG. 14. METHODS OF PROVIDING FOR HOLES IN DROP FORGINGS

is fed through the press, each stroke producing a finished piece. Dies of this kind are sometimes called tandem dies. An example of this die is shown in Figure 15. It will be seen that the work "A" has three separate operations all performed upon it in the same die, and yet at each stroke of the press a completed piece is turned out.

Gang dies, are often used for small parts in order to save waste metal and, at the same time, to produce work more rapidly. An example is shown in Figure 16. This illustration shows that several pieces may be made at one stroke of the press with a comparatively small amount of wasted metal.

A compound die is one that is arranged in such a way that the punch and die portions are not separated but are combined in such manner that the upper

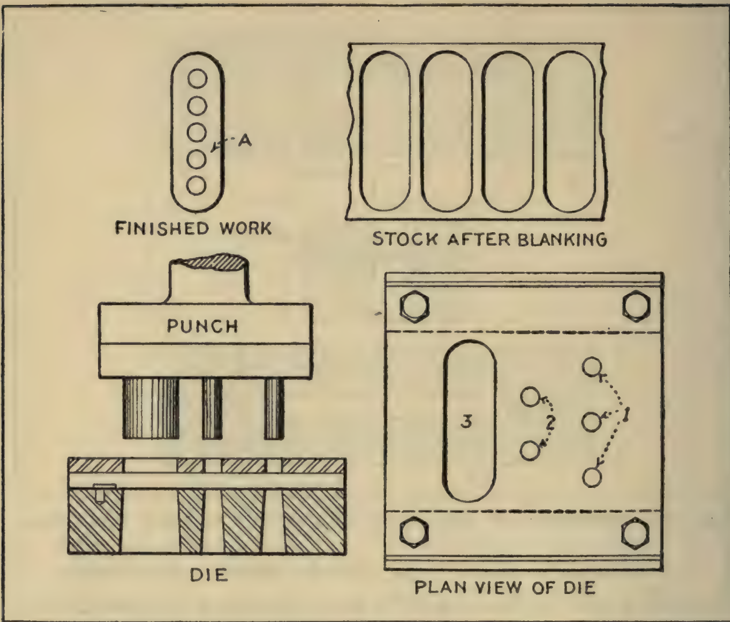

FIG. 15. AN EXAMPLE OF A FOLLOW OR PROGRESSIVE DIE

and lower half each contain a punch and die. Such a die has its stripper springs adjusted so that they are strong enough to overcome the cutting resistance of the stock, after which they are compressed until the end of the stroke is reached. In a compound die all the operations are carried out synchronously while the stock is firmly held; therefore, the work produced by this type of die is more accurate than those previously described. It is not as simple a die, however, and it requires much more care in setting up.

Forming dies are used for work of hollow form, a cavity being made in the die into which the work is

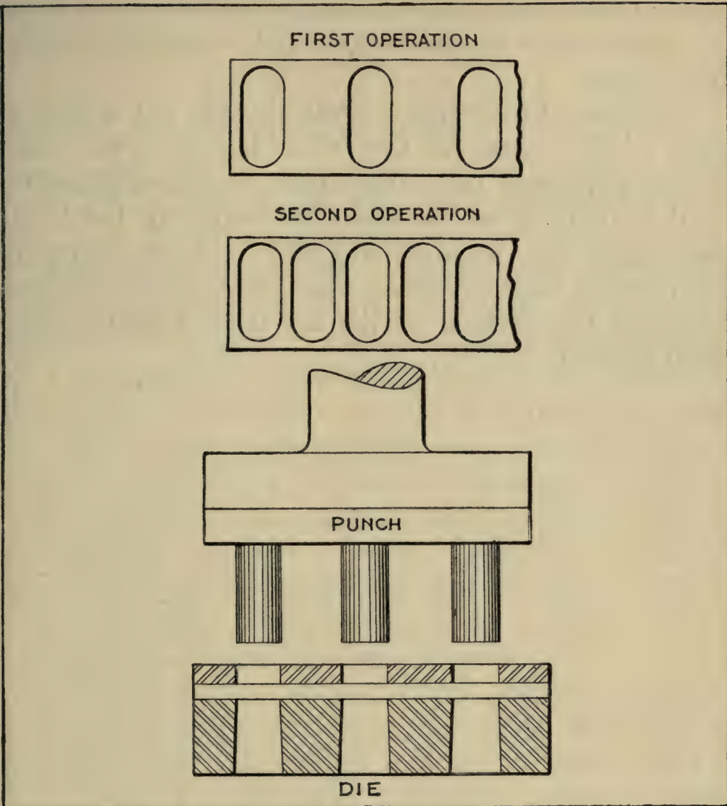

FIG. 16. AN EXAMPLE OF A GANG DIE

forced by the press. Drawing dies are used for much the same class of work as forming dies; but in the process of drawing, the flat blank which is being formed is held rigidly between the surfaces of the die so that wrinkles will not form during the drawing operation. Curling dies and bending dies are used respectively for turning over the edges of sheet

metal pieces and for bending the surface of a piece of work into a partial curve, not, however, a complete circle.

Sub-press dies, strictly speaking, are not a special class of die except in the sense that the punch and die are combined in a single unit by means of guides so that there is no necessity for lining up the lower and upper dies when setting up. A high degree of accuracy is assured when this class of die is used, although the expense of the die itself may be somewhat greater.

CHAPTER III

DRILLING, BORING, AND REAMING

Drills.—Drills may be considered as one of the most important factors in producing work in any manufacturing plant. A drill must not be considered as a finishing tool, however, although it is possible, if the drill is carefully ground and the work painstakingly performed, to produce a clean hole quite close to the size of the tool. For many classes of work a drilled hole answers every purpose, and if followed by a reamer a smooth hole of any required diameter may be readily produced. For bolts or other fastenings of similar character a drilled hole is usually considered commercially good.

As in other types of tools, drill shapes and forms are dependent to a certain extent on the class of material upon which they are to be used. Almost any kind of a pointed tool will drill a hole if revolved under pressure, but in order to produce the work properly the drill shape must be suited to the material to be cut. As a preliminary operation in drilling a long hole, it is often advisable to spot the material with a short drill. The stiffness of the short tool is an advantage to start the hole in the right place and not run any chance of the deflection which might take place if a long drill were to be used first. Further-

more, a considerable saving in drill grinding will result, as the short drill gets through the scale on the work and leaves the long drill to take a clean cut under the surface of the scale. This treatment is of marked advantage in drilling forgings on the turret lathe.

Drills in common use are shown in Figure 17. The spotting drill, A, is ground to an angle of 40 degrees in order that the following drill may commence its cut on the lips and not on the point; it will then cut more freely and get a better start in the work. The manner in which the cutting action takes place with the following drill is clearly shown in the diagram at B.

The drill, C, is little used in general manufacturing,

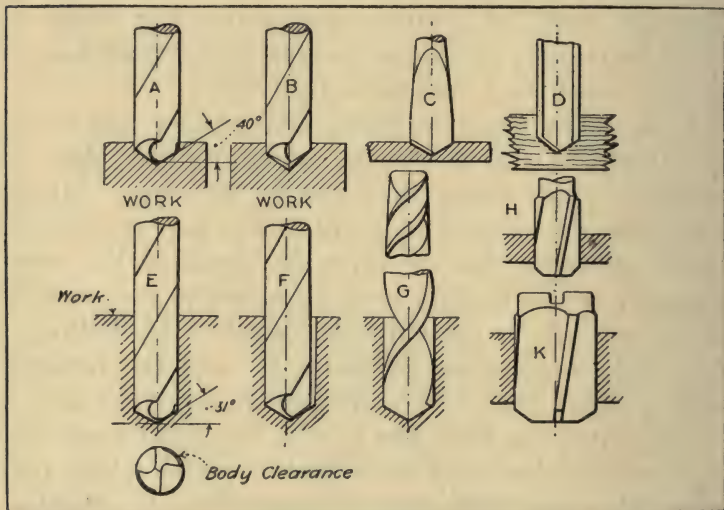

FIG. 17. VARIOUS TYPES OF DRILLS

but it is an important item in the equipment of the blacksmith or metal worker. A drill of this type is not suited to deep holes, although is particularly adapted to thin work. It has no twist, and therefore does not have a tendency to tear and break the metal as it passes through the work. The wood drill, D, is often used by cabinet makers and other wood workers. This drill also has no twist, but is partly cylindrical with a groove for chips on each side.

The ordinary type of twist drill, E, is used in general manufacturing work. The angle at which it is usually ground, indicated in the illustration, is about 31 degrees, but the angle of the twist cut varies in different makes; sometimes it is uniformly twisted throughought its length and again it may be made with, what is termed, an increase twist to give greater strength in a long drill. Twist drills were originally made by twisting up a piece of flat stock, but the present method of manufacture is to mill the helical grooves from a round bar of steel. A shank is provided in order properly to hold the drill and drive it through the work, this portion being either straight or tapering. If straight it may be held in a drill chuck or in a plain bushing with set screws, but if the shank tapers, it is provided with a flatened end, or "tang," which acts as a driver in the drill socket. A modern twist drill has a slight "back taper" running longitudinally from point to shank so that it will work with more freedom. Body clearance is also provided as indicated in the end view of the tool shown in the illustration. The purpose of the two clearances is to avoid the heating of the drill by

friction in the hole and also to make the cutting action easier.

The cutting angles of the lip of the drill vary from 59 to 76 degrees depending on the material which is to be drilled; ordinarily a drill for steel and iron is ground to 59 or 60 degrees, while for brass the angle may be around 75 degrees. It is of the greatest importance that drill angles should be equal, for unless this is the case the hole will be cut too large, as indicated at F, since the tool is working around a false center which is not the actual center of the drill stock itself. In such a case the longest lip governs the size of the hole, as may be readily seen.

Another type of twist drill, G, is known as a flat twist drill. As made by some manufacturers it has a flat shank requiring a special form of socket for holding. The Pratt & Whitney Co. make the form illustrated in which an increase of twist is given to the shank portion to provide additional surface which is ground to fit the taper in a standard socket, thus doing away with the necessity for special sockets. The advantages claimed for this type of drill are that it has greater chip clearance and higher productive capacity.

Core Drills.—When holes are to be drilled in cast iron or other cast metals in which the holes have been cored, another type of drill, often termed a "core drill," is used. Drills of this kind, H, Figure 17, are listed by manufacturers as "three-groove chucking reamers." It may be noted that the end of the drill does not come to a point, as in the case of the regular twist drill, but is blunted because it has no work to

do at the center. The three flutes tend to keep the tool in a central position while drilling. Four flutes instead of three are sometimes used. In the larger sizes shell drills, K, are found to be capable of very severe service. They are held on an arbor like a shell reamer and are generally four fluted.

An important point in connection with the use of core drills is that any variation or eccentricity of the cored portion of the work is likely to affect the tool to a considerable extent so that the resulting hole is not true with the remainder of the work. This trouble can be easily avoided by truing up the hole for a short distance with a single-point tool before inserting the core drill, as indicated in Figure 18.

Counterbores.—When a shouldered hole is to be made, such as that shown in Figure 19, the counterbore is generally employed. In order to have the two holes concentric, two methods are possible: In one the

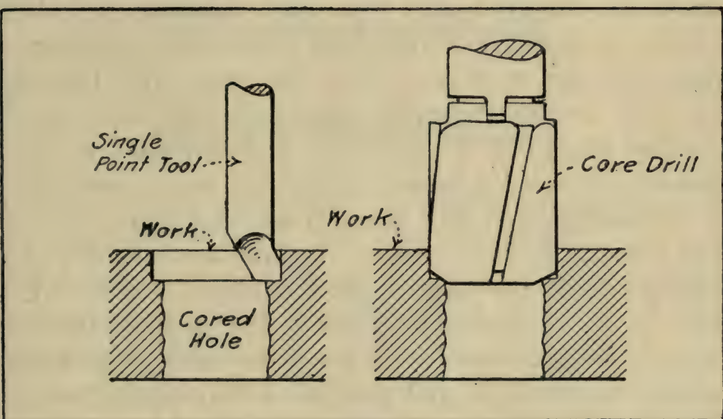

FIG. 18. STARTING A HOLE WITH A STARTING TOOL PRIOR TO THE USE OF A CORE DRILL

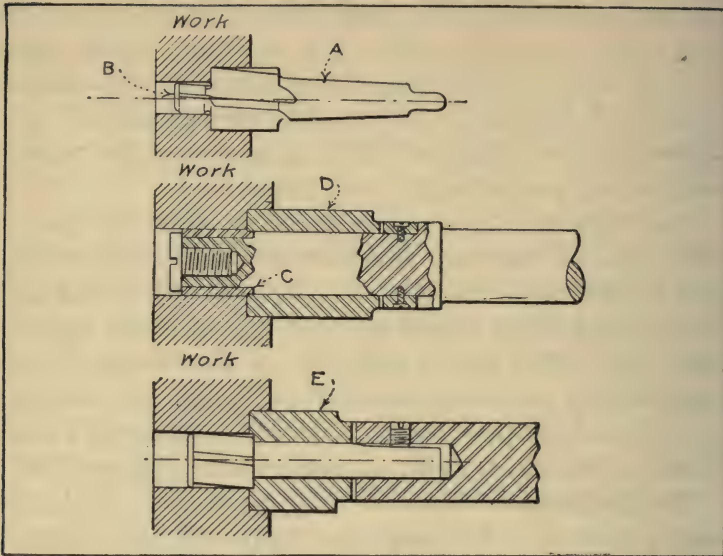

FIG. 19. VARIOUS TYPES OF COUNTERBORES

work is revolved and the cutting tools are held rigidly without revolving; the holes can then be produced by two or more cuts of the tools after they are set out to the required diameters. In the second method the work is stationary and the tools revolve; the smaller hole is usually made first and a tool called a counterbore, A, like that shown in Figure 19, having a pilot, B, which enters the smaller hole, does the remainder of the cutting on the larger diameter. It will be noted that the action of the pilot in the previously drilled small hole tends to steady the action of the counterbore and produce a concentric hole.

Several varieties of counterbores are in use, the principles of which are the same as that shown at

A. One type, D, has interchangeable blades or cutting lips and removable bushings, C, which allow work to be done in holes of various diameters. Another type, E, also has a removable pilot, which can be provided with cutting heads of different diameters, but the pilot does not revolve. If work requiring a high degree of accuracy is intended, the type with a revolving pilot is advisable. Some cases occur when it may be possible to extend a pilot somewhat smaller than the hole, so that it can be guided in a bushing beyond the work itself. In either of these cases there is little danger of injury to the finished surface of the smaller hole.

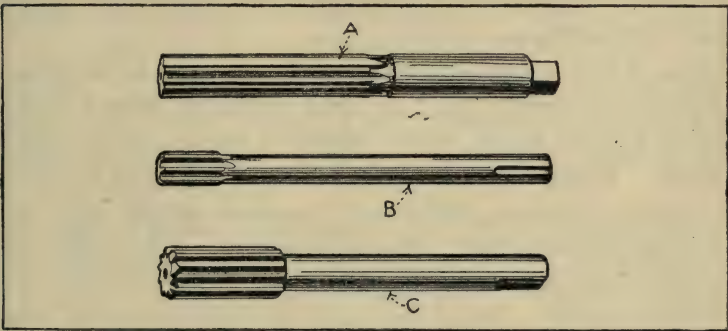

FIG. 20. (A) HAND REAMER. (B) PLAIN FLUTED CHUCKING REAMER. (C) ROSE CHUCKING REAMER

Reamers.—When a hole is to be accurately finished to a given diameter it may either be bored to this size by successive cuts of the boring tool or it may be reamed. A reamer, therefore, may be considered strictly as a tool for sizing a hole. Several types of reamers are in common use and the selection of the type for any particular work depends upon the ma-

terial to be cut, the diameter of the work, and the previous operations which have been done upon it. As reamers are used entirely as finishing tools, the amount of metal which they remove is small and is dependent upon the diameter of the hole and the nature of the metal.

A group of reamers of various types is shown in Figure 20; while the types here represented do not include every variety, they may be considered as representative. The simplest type in common use is the plain fluted hand reamer, shown at A, which has a squared end to which a wrench or holder can be applied for the purpose of forcing the reamer through the hole. Reamers of this kind are sometimes made with spiral flutes.

The plain chucking reamer, B, in the same illustration, is largely used in drill press or turret lathe work and is made with either a taper or straight shank. When used in turret-lathe work it is held in a floating holder, different types of which are described under their proper heading. The type of fluted chucking reamer shown at B may have the flutes equally spaced around the periphery of the reamer or they may be staggered so that no two tooth spacings are exactly alike. The object of this arrangement is to prevent "chatter."

Another type, called a rose chucking reamer, C, is intended for work of a fragile nature or for thin work which might be distorted in reaming with an ordinary coarse-fluted reamer. The rose reamer has wider "lands" (space between indentations) and is not lipped like the chucking reamer previously men-

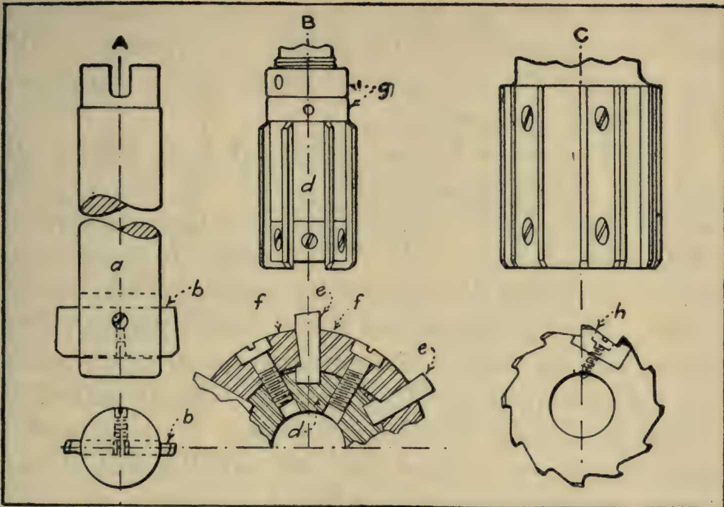

FIG. 21. TYPES OF INSERTED-BLADE REAMERS

tioned. It should cut only on the end, and the object of the wide lands on the flutes is to preserve a bearing surface and thus tend to produce greater accuracy in the work.

Inserted-Blade Reamers.—The simplest type of inserted-blade reamer is the tool shown at A in Figure 21. This reamer is never used with a floating holder, the design being such that the blade, b, floats in the holder, a. For certain classes of work, especially vertical work, as on a vertical boring mill, reamers of this type may be made to do excellent work. Upkeep is provided for by means of a tapered screw and a slot in the blade whereby the blade may be expanded and reground. On account of the cost of high-speed steel later developments in the design of reamers favor the inserted-blade type so made

that the blades can be removed and replaced at a nominal expense. By this means the upkeep of the tool is quite low: a number of styles can be purchased in the American market.

A good example is that shown at B in Figure 21, made by the Pratt & Whitney Co. In this type of reamer the body, d, is provided with tapered slots in which the blades, e, fit. The clamps, f, in the sectional view, lock the blades by means of the screws shown. Various diameters within the capacity of the reamer can be readily made by manipulating the locking nut shown at g. It is a very difficult matter to change a reamer adjustment of this kind in such a way that all the blades will cut equally, but it is a simple matter to regrind to the desired size after setting the blades slightly oversize to allow for the grinding.

Another excellent type of inserted-blade reamer is shown in the same illustration at C. In this type the body of the tool is cut out, as indicated, to receive the blades, h. It will be seen that these blades are so made that each forms two teeth, and are held in place by the screws shown. When a reamer of this kind becomes worn so that it does not size the work properly, the blades may be removed and strips of paper inserted under them, after which they can be reground to the desired size.

Taper Reamers.—Before reaming a tapering hole, the first essential is that the bored hole be true and straight. When the taper is very "shallow"—i.e., the angle of the taper very slight—a single reamer can be used, as, for instance, in making a taper pin

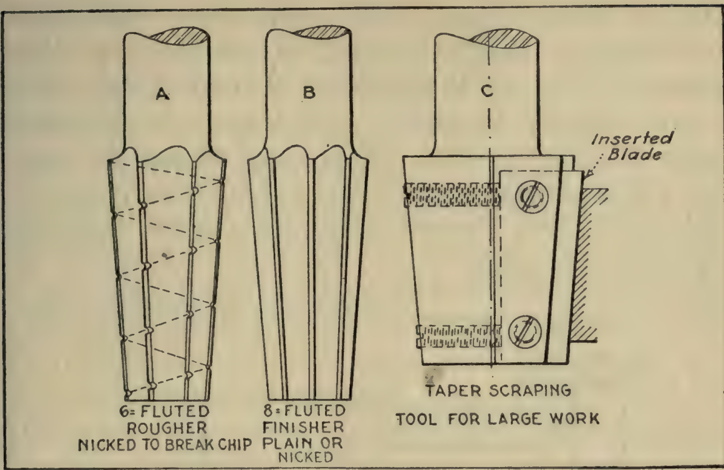

FIG. 22. TYPES OF TAPER REAMERS

hole; but when a more obtuse angle is required several tools may be necessary to produce the final taper. For this latter work the first two reamers may be made as indicated, in Figure 22, at A and B. In the tool, A, the flutes are cut straight but are threaded or nicked to "break the chip" and make the cutting action easier. In order to overcome the tendency toward "drawing in," a slight left-hand spiral may be given to the flutes, the angle of the spiral being dependent somewhat on the angularity of the tapered hole. It is also advisable in some cases to space the teeth unequally to avoid chatter which is more likely to occur in taper than in straight reaming. Taper reamers should be made longer than the holes in which they are to be used in order to provide for upkeep. Roughing reamers should have fewer flutes than the finishing tool for greater chip clearance.

Taper reamers are occasionally made for large work with a single inserted blade, such as that shown at C in the illustration. A tool of this kind is not, strictly speaking, a reamer, but is more nearly a scraping tool. This type of tool is valuable for some classes of work, however, as it can be adjusted to size very readily and can be reground a number of times.

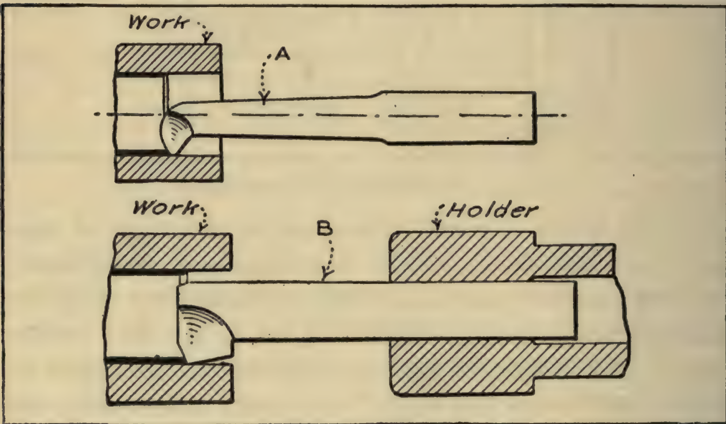

FIG. 23. SIMPLE TYPES OF BORING TOOLS

Boring Tools.—The engine lathe is generally used when a hole is to be bored in but one piece of work which can be revolved. The type of boring tool used for small holes under these conditions is shown in Figure 23 at A. Due to its construction, a tool of this kind is only suited to very light work, and a number of cuts must be taken to bring the work to the required size. As such tools are seldom used to any great extent in manufacturing work, it is

unnecessary to mention their shortcomings. They serve the purpose for which they are intended—boring holes in jigs and the like, and therefore need no further comment. Tools of a similar character but somewhat heavier are occasionally used in turret lathe work for boring short holes, although a boring bar is generally used when the size of the hole will permit. When a boring tool of this type must be used for manufacturing work, it is better to make it in the form shown at B in the illustration. It will be seen that this tool has a more substantial nose and that it is ground to a different shape than the toolmaker's tool shown at A in the illustration. It will give very good results on short work.

When a turret lathe must be used to bore a hole and the size of the hole will permit, it is better to use a bar such as that shown at A in Figure 24. Single-point tools, or tools having but one cutting edge, will produce more accurate work than multiple-cutting tools, although they will not turn out the work as rapidly. The bar, B, made in a variety of ways to suit different conditions, is used in many classes of work. The tool, placed straight across the bar, is held with a set screw or a taper pin, and may or may not have the added refinement of a backing-up screw to make adjustment easier. The bar may be piloted in a bushing of some kind, or it may be as shown in the figure. If several diameters are to be machined at the same time a multiple bar, C, can be used to good advantage, the general points in construction being much the same.

Flat-Cutter Boring Bars.—For rapid production flat cutters are frequently used in bars such as shown at D, Figure 24. The advantage obtained by the use of two cutting edges is that the amount of work performed by each cutter is less than with a single-point tool, and therefore the feed can be somewhat increased. The disadvantage lies in the fact that diameter sizes are soon lost on account of re-grinding, while the single point tool can be re-set to a given diameter a number of times through a simple adjustment.

For very heavy cutting a cutter head is made up similar to that shown at E in the illustration. In boring automobile cylinders, or other work of similar character, tools of this kind can be used to advantage, but it is highly important to have all the cutting points ground to the same diameter and angle so that they will do an equal amount of work. Bars of other varieties besides those shown are used in general manufacturing, but the working principles are much the same as the ones described.

Adjustable Boring Tool for Tool-Room Work.—The requirements of the toolmaker are somewhat different from the requirements in the manufacturing departments. Therefore the type of boring tool which he is likely to favor will differ from those previously described and may take the form of that shown in Figure 25. This tool will probably be provided with a taper shank, A, which will fit the tailstock of the lathe. The cutting tool itself is small and is held by two screws, as shown, in the swinging block pivoted at B in the body of the toolholder. The two screws,

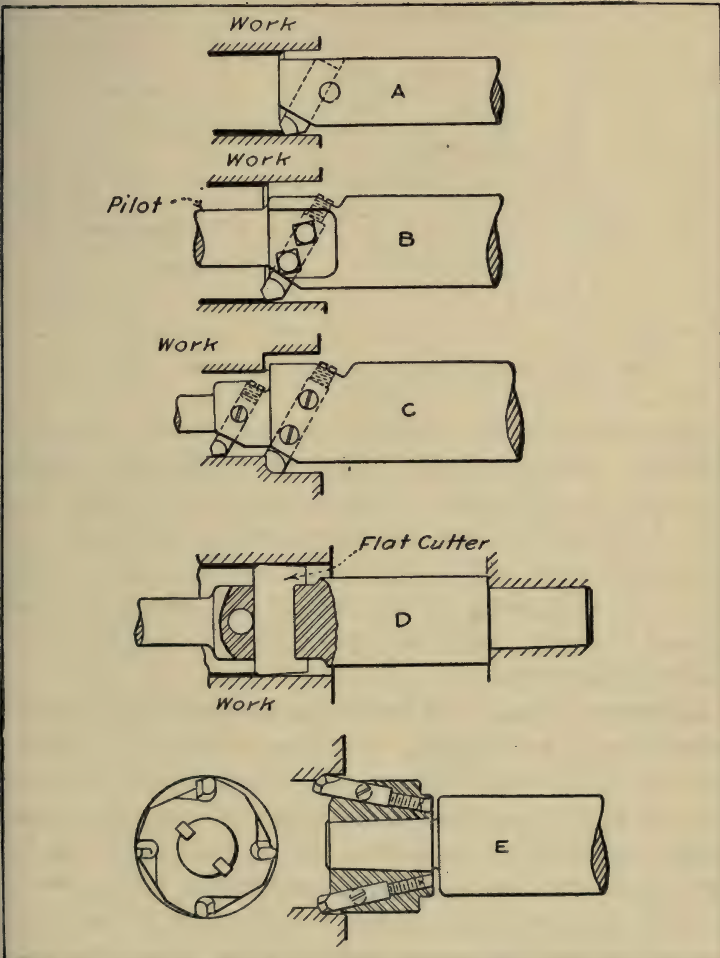

FIG. 24. VARIOUS TYPES OF BORING BARS

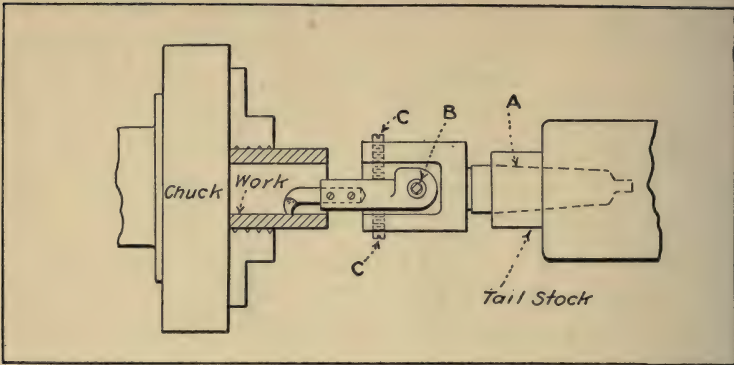

FIG. 25. TOOLMAKERS' ADJUSTABLE BORING TOOL

C, C, are used for adjustment, one being loosened and the opposite one tightened until the desired diameter is obtained. Other varieties of this tool may be found in any manufacturers tool room. A toolmaker will often have one of his own make which is of course "superior to all others." For boring bushing holes in jigs, tools of this sort are almost indispensable.

Recessing Tools.—In turret lathe work it is often necessary to produce a recess or groove in the inside of the work. When the work is of medium size, so that a good-sized tool can be used, no particular difficulty is experienced, for the work can be done by a number of different methods. If the work is done on an engine lathe, a tool may be conveniently held on the cross slide of the lathe, as indicated at A, Figure 26, and the carriage can be withdrawn until the tool has reached the proper depth, after which it can be fed along the distance re-

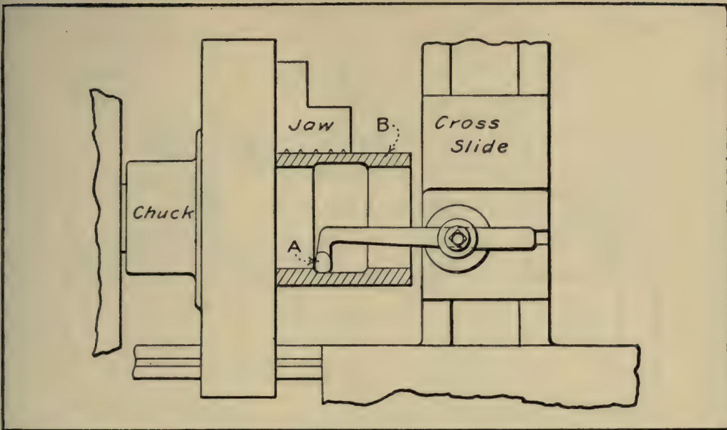

FIG. 26. A SIMPLE RECESSING TOOL ON AN ENGINE LATHE

quired to produce the work, as shown at B. It must be remembered, however, that many varieties of turret lathes do not have a cross-sliding movement to the turret, nor does the cross slide in some other varieties have a longitudinal power feed. Hence, it is necessary to design a recessing tool in such a way that it will be self-contained and have its own moving parts, irrespective of the turret movement.

Much depends upon the nature of the groove to be cut. If it is narrow, such as that shown in Figure 27, it is easily possible to build a tool of a very simple character to be operated by the workman. In this case the tool consists simply of a body, A, in which the holder, B, is set eccentrically to the center line of the spindle and at a sufficient distance to give the depth of cut desired. The handle, C, furnishes the necessary feed.

When a recess is cut deeply into the work, and

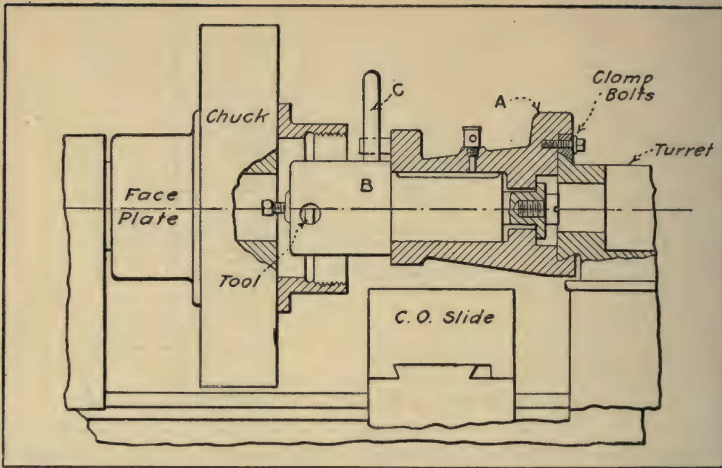

FIG. 27. SIMPLE RECESSING TOOL FOR TURRET LATHE WORK

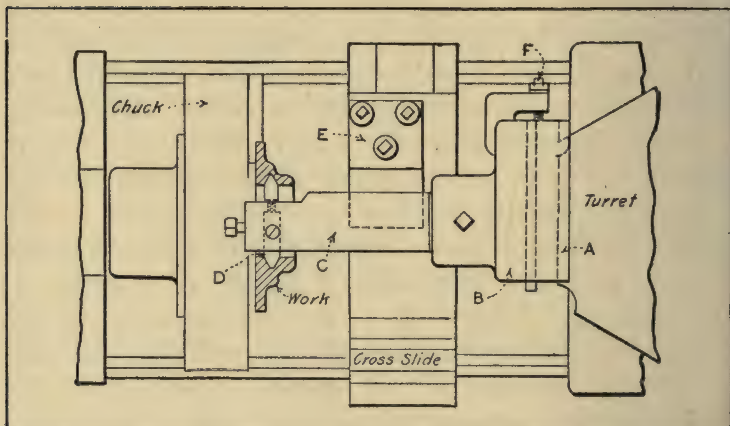

FIG. 28. RECESSING TOOL FOR TURRET LATHE

when the tool extends a considerable distance from the turret face, a scheme such as that indicated in Figure 28 can be utilized to good advantage. In this case the body of the tool, A, is mounted on the turret and contains a sliding member, B, in which is mounted the recessing bar, C, having a tool at "D". Assuming that there are tools on the front of the cross side, which are used in connection with the work, and that the rear of the slide is supplied with a support, E, by means of which the recessing bar is supported and fed into the work by withdrawal of the cross slide; it will be seen, then, that a movement of the slide will carry the tool into the work as deeply as permitted by the stop screw, F. The slide carrying the recessing bar is controlled by a spring, so that when the feeding pressure is released the spring will return the slide to its normal position.

Extraordinary cases occur occasionally in machine shop practice when a number of parts must be made which call for more elaborate tooling than is ordinarily required. An example of this sort is shown in Figure 29. In this case, the work, A, is a steel casing with two recesses equidistant from the center line as shown at B. The work is of large size and requires a 20-inch swing turret lathe to handle it. It will be seen that the two recesses are in such positions that they can not readily be machined. As a support for any tool making this cut is necessary, a bushing has been inserted in the fixture to hold the piece so that a pilot can be used on the bar for recessing. This bar has been drilled to receive a rod,

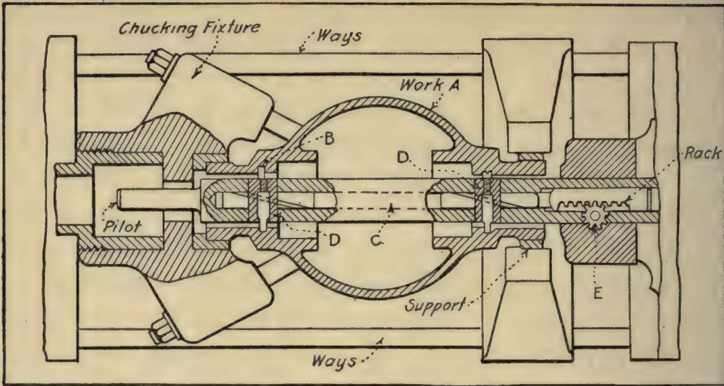

FIG. 29. AN ELABORATE RECESSING TOOL FOR A LARGE STEEL CASING

C, on which two angular splines have been cut. The splines engage with the two small tool blocks, D, which hold the recessing tools. The mechanism is operated by means of a pinion, E, which engages with a rack cut on the operating bar, as clearly indicated in the illustration.

It is obvious that any tool of this kind would not be built unless very many pieces were to be machined, as it would not prove economical otherwise because of the high first cost. For the work shown, however, some thousands of pieces were to be made, and the elaborate equipment paid for itself many times over in the saving of time and in the accuracy of production. As the depth of the recess on this piece was rather important, it was essential that the spacing of the grooves should be symmetrical about the center line, which also made the tool so much more essential.

CHAPTER IV

TURNING, FORMING, AND THREADING

Hollow Mills.—In roughing-down bar stock similar to the piece shown at A in Figure 30, a hollow mill is frequently used, but this type of tool is not to be recommended for accuracy. But as it has several cutting lips it will remove stock rapidly and can be used for roughing operations to good advantage. The ring, B, is used to prevent the lips of the tool from springing and also to make small adjustments by drawinig in the lips to a slightly smaller diameter when necessary, but the adjustment obtainable on this type of hollow mill amounts to only a few thousandths of an inch. An adjustable type such as shown at C, is much more expensive but possesses some advantages. The cutting tools, D, D, are of the inserted type and are controlled as to their diameter by a ring with cams cut upon it which engage with the cutting tools and force them in or out as desired. Although a tool of this type can be more accurately adjusted to a given diameter than the one previously described, it will not remove stock in as great a quantity nor has it the desirable features of chip clearance that the former tool possesses.

Another type of hollow mill designed for exceptionally heavy cutting and large stock reduction is

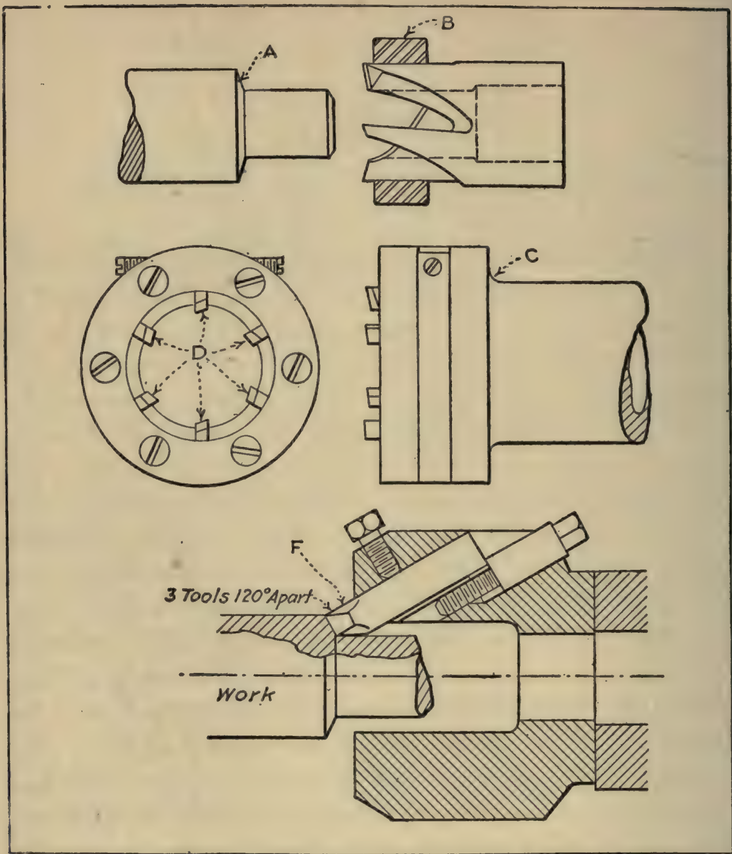

FIG. 30. SEVERAL TYPES OF HOLLOW MILLS

shown at E. This tool is of special character and is designed for a single purpose. It will be noticed, however, that the cutting tools, F, are adjustable and that they are heavy in section so as to carry away heat rapidly. Tools of this sort are designed only for the most severe service and are not economical

unless stock reductions are large and a great number of pieces of the same character are to be machined. An important point in connection with all hollow mills is the back clearance which, on the type shown at A should be at least an eighth of an inch to the foot. The cutting edges of hollow mills should be a trifle ahead of the center for steel work but on center for brass.

Turning Tools.—On turret lathe work tools used for turning are made up in a different way from those employed on the engine lathe. On the engine lathe the tools are held on the cross slide of the machine in suitably designed tool holders, while in turret lathe work the holders are mounted on the turret and the tools are held either horizontally or vertically. One of the simplest types of turning tool is shown in Figure 31, the holders in this case being

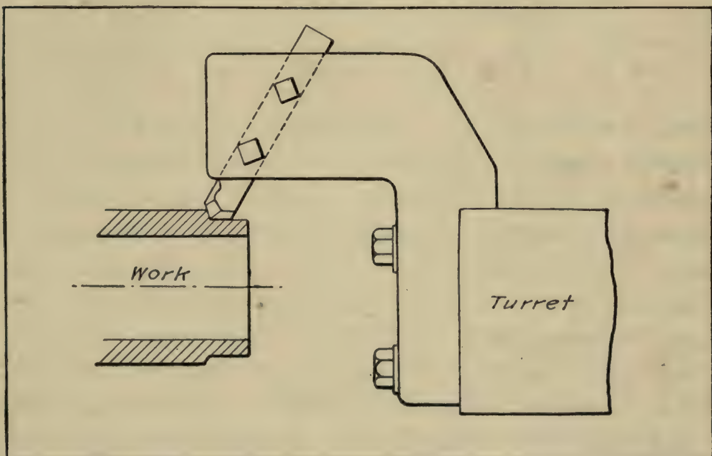

FIG. 31. A SIMPLE FORMING TOOL FOR TURRET LATHE WORK

made of cast iron and bolted to the turret face. The tool is set at an angle and is held in place by two set screws. Adjustments for diameters can be readily made within the capacity of the tool. For short lengths and small diameters, a tool of this kind will give excellent results; but when the work is long, as in the turning of bar work on a screw machine, it is necessary to provide support for the work opposite to the cutting point of the tool.

A simple type of tool for this latter purpose, usually termed "box tool", is shown in Figure 32. The

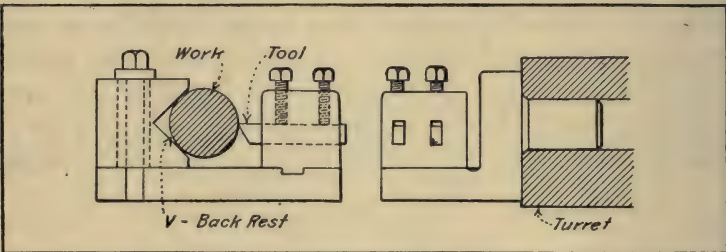

FIG. 32. A SIMPLE BOX TOOL FOR TURRET LATHE WORK

tool is mounted in a block opposite to which a V-shaped supporting block is so placed that it can be adjusted to the diameter of the work being cut. Makers of turret lathes have developed a great variety of tools along these lines to suit the particular machine which they manufacture. For small screw-machine work, box tools with two or more adjustable blocks are frequently made which are extremely useful for automatic and light hand-screw machine work.

Adjustable Turning Tools.—For bar work it is very desirable to have tools which can be adjusted rapidly

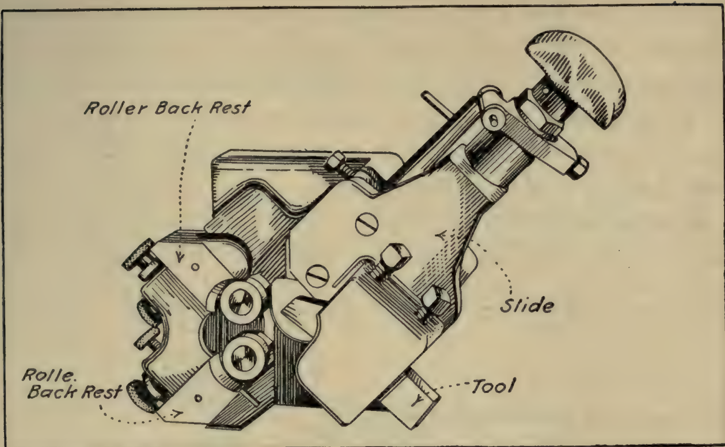

FIG. 33. ADJUSTABLE TURNING TOOL WITH ROLLER BACK RESTS
Pratt & Whitney Co.

to various diameters within their capacity, and on turret lathe work several tools of the styles shown in Figure 33 may be mounted on the turret and control several diameters on the bar. Such tools are made with both roller-back and V-back rests, the back rests being adjustably mounted so that they can be used either for following or leading. When used as following back rests, they are set to the diameter at which the tool is at work and slightly behind a point opposite the cutting tool. When used as leading back rests, the material must either be bright rolled steel or it must have been finished to a given diameter in a previous operation. Leading back rests can never be used on rough stock; but following back rests, as they work directly behind a surface which has just been finished, are always used in rough stock turning. The difference between the use of the

V-back rest and the roller-back rest is that the rollers are less likely to mar the work, while V-back rests may cause slight abrasions, especially if work is done at high speed. However, on automatic work of small diameter the V-rests are commonly used with perfectly satisfactory result.

Open-side Turning Tools.—The tool shown in Figure 34 is used for turning short lengths when the

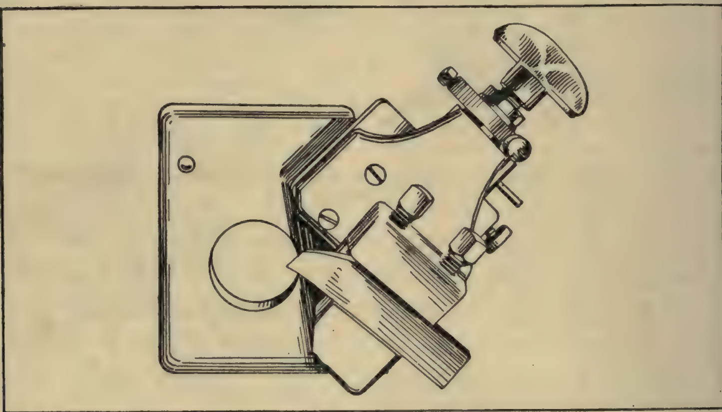

FIG. 34. OPEN SIDE TURNING TOOL
Pratt & Whitney Co.

work is held rigidly; therefore it does not require back rest support. A tool of this nature is adjustable to different diameters within its capacity, and sometimes possesses an added refinement in an adjustable stop or an index on the screw so that it can be set for different diameters for both roughing and finishing cuts.

Overhead Turning Tools.—It is important that any type of turning tool should be held rigidly to avoid

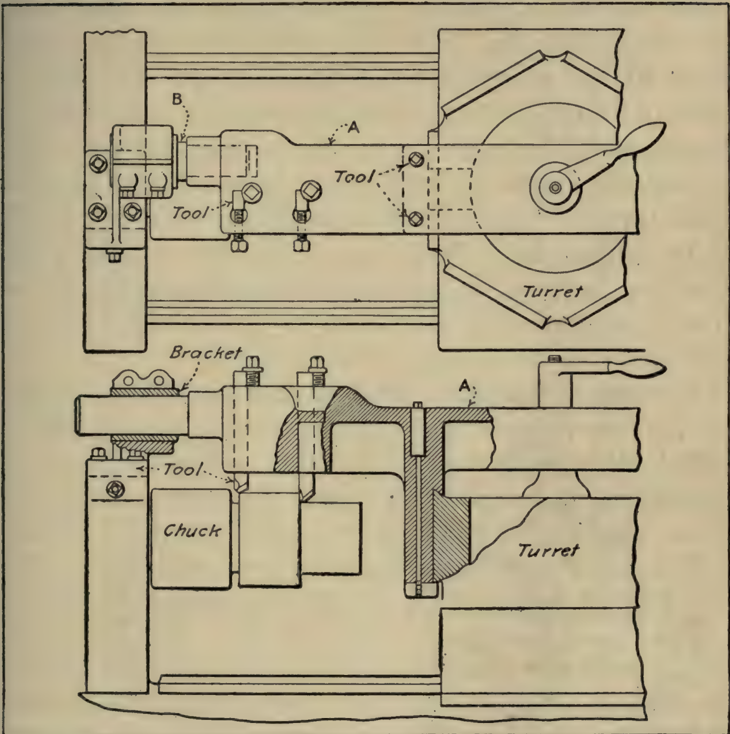

FIG. 35. SPECIAL PILOTED TURNING TOOL FOR RAPID PRODUCTION

the chatter resulting from excessive vibration. For this reason turret lathe tools for heavy classes of work—such as castings, forgings, and the like—should be so constructed that they will have ample section to withstand cutting strains without springing away from the work. For manufacturing work in large quantities, special tools are frequently built such as that shown in Figure 35 at A. It will be seen that this tool is mounted on the turret of the turret

lathe and has additional support from the pilot bar, B, which enters a bushing in a bracket on the head stock of the machine. The several tools are removable and adjustable, so that they can be replaced and reground when necessary. Such tools are not intended for universal use but are specially designed to meet the requirements of a particular case. It is always advisable, in making up a tool of this kind, however, to provide as much latitude as possible, so that in the event of a change in design the tool can still be used with slight modifications.

Turning Tools for Vertical Boring Mills.—Many people do not consider that the vertical boring mill is sufficiently adaptable to handle special classes of manufacturing work to good advantage, but its power and stability are such that, if properly tooled, it will prove a valuable manufacturing machine. The majority of boring mills in use throughout the country are not run anywhere near to their maximum efficiency. Only a short time ago, while investigating conditions in an old factory, I discovered three boring mills at work continuously, yet only turning out about one-fifth of the product which they should have accomplished. When the Superintendent was asked why these machines seemed to be such small producers, he informed me that they turned the work out "as fast as the assembling room could use it," so he had no fault to find.

The multiple turning tool head shown in Figure 36 gives an idea of the adaptability of multiple tools to a vertical boring mill when the product is sufficiently large to warrant a little expenditure for tools.

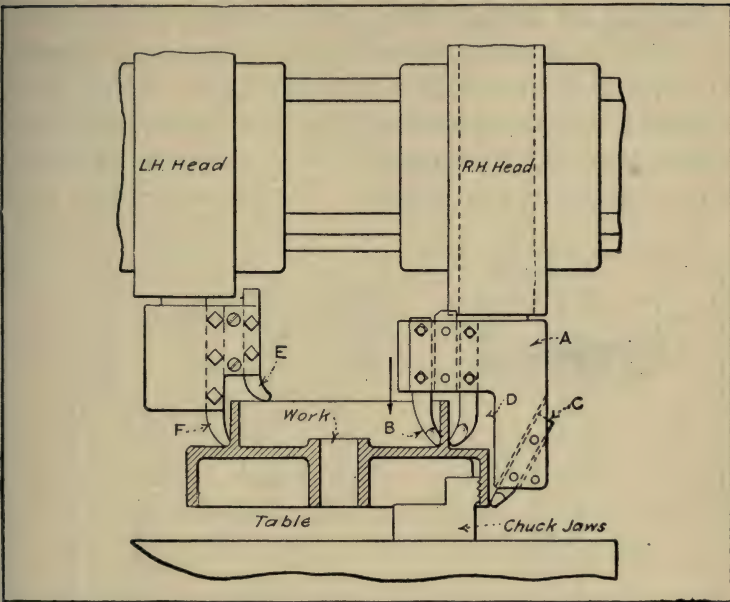

FIG. 36. SPECIAL TURNING TOOLS ON A VERTICAL BORING MILL

In this case the heavy tool holder, A, contains three tools, B, C, and D, which all work simultaneously on the casting. At the same time the two tools, E, and F, in the left-hand head are at work facing the surfaces indicated. It is unnecessary to go into the matter of turning tools on the vertical boring mill to any great extent as the more modern machines used in manufacturing are provided with a side head in addition to a turret, each containing a number of tools. When a machine of this type is used, the side head provides a means of setting up four or more tools to be operated in sequence, and adjustment of the side head permits diameter settings to be easily made.

Cutting-off Tools.—The ordinary type of tool used for cutting off work which has been previously turned or formed is shown in Figure 37 at A. Such tools, however, are uneconomical, for after grinding a few times, they must be annealed and reforged, or drawn out to their former length. The inserted-blade type

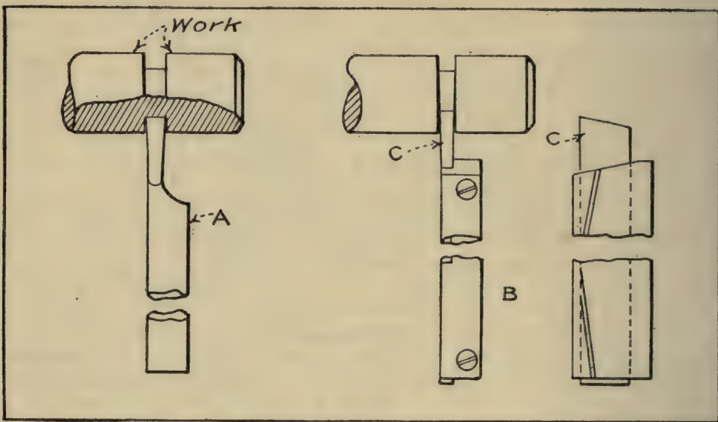

FIG. 37. TYPES OF CUTTING-OFF TOOLS

of cutting-off tool, shown at B in the same illustration, is much more economical, for it is so designed that the blade, C, can be clamped securely in the holder and adjusted to any desired position without difficulty. The holder is so made that it will fit several different sizes of tool posts, thereby making its adaptability to different classes of work and different machines so much the greater. In the holder shown, the blades can be bought ready-made to slip into the holders, and only require an occasional grinding to keep them in condition.

Threading Tools.—The simplest form of threading tools is the forged tool shown at A in Figure 38. Such a tool is used for plain threading on the engine lathe and needs no particular comment as the nature of the operation is so well known. In any threading

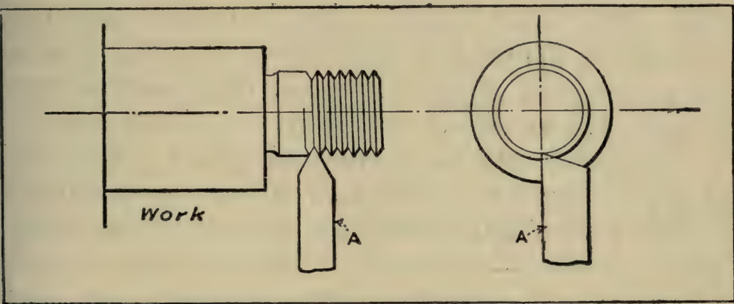

FIG. 38. THE SIMPLEST FORM OF THREADING TOOL

tool there are two essential points; first the correct shape of the tool itself, and second, its setting in relation to the work. If a threading tool is ground to the correct angle on its sides and is set on the center of the work, it should produce a threaded form of the correct angle. If, however, it does not come into contact with the work at the proper point, and if the cutting face is tipped one way or the other to bring the point on center, the resulting angle of thread will not be correct.

Because of these facts, it is evident that the greatest care must be exercised both in grinding and in setting any sort of threading tool. In turret lathe work, threading tools of the single-point variety can not be used unless the machine is provided with a

thread-chasing attachment whereby the lead of the screw can be properly controlled. There are many cases, however, when such an attachment is a great advantage, and it is in cases of this kind that a special design of cutting tool is desirable. When the thread-chasing attachment is applied to the cross slide of the machine, an ordinary type of tool may be used for the work if desired; but when the threading attachment affects the turret slide, another type of tool may be found necessary.

If the work calls for an interior thread, a bar, such as that shown at A in Figure 39, can be used with a tool of the single-point type, as B, or of the chaser

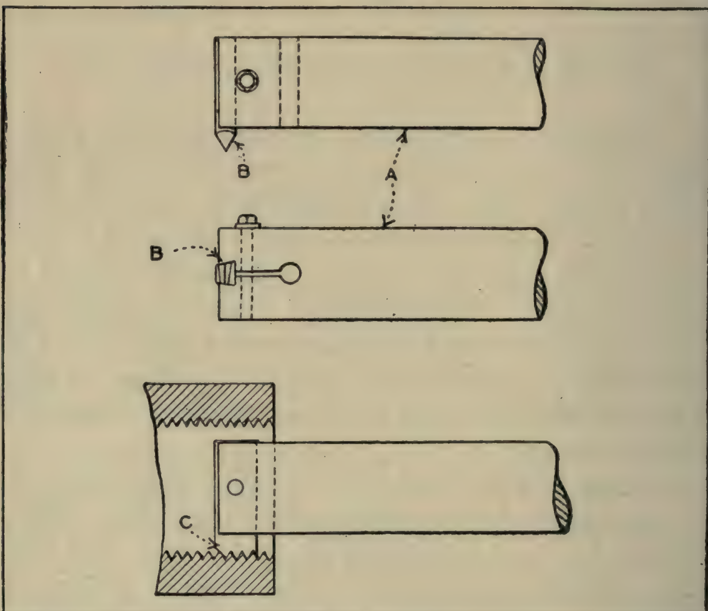

FIG. 39. TYPES OF THREAD CHASING TOOLS

type, as C. This bar must be held in a special holder on the turret, which provides for quick withdrawal and a micrometer stop for depth. A tool slide of this sort can be easily applied to the turret of the machine and presents no great difficulty in the matter of design. When the turret itself has cross-sliding features and a micrometer dial adjustment, there is no necessity for an extra tool holder of the type mentioned.

Goose Neck Threading Tool.—Due to the peculiar construction of a threading tool it is very likely to chatter under the cut. As chatter is caused by a rapidly repeated springing away of the tool from the work and by an equally repeated digging in again, both tool and work should be held so rigidly that such vibration will not be possible. Such a condition is difficult to obtain, however, and therefore the tool may be so constructed that it will never have a tendency to dig in. A special tool of this nature, made especially for threading work on the turret

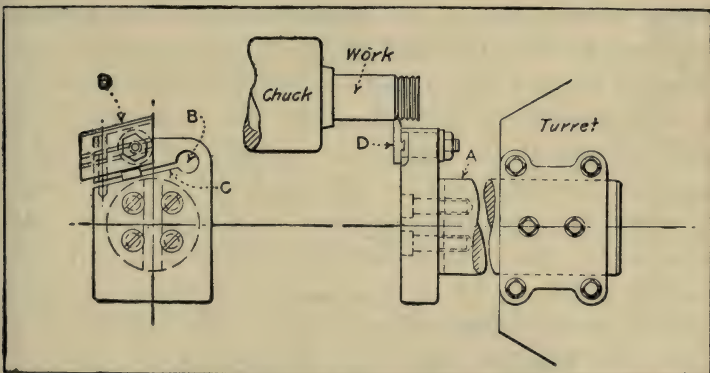

FIG. 40. A GOOSE-NECK THREADING TOOL FOR TURRET LATHE

lathe, is shown in Figure 40. The tool-holder body is mounted on the bar, A, which is held in the turret of the machine. The body is drilled at B and slotted at C to allow for springing action. The threading tool, D, is locked in position and is ground to the correct angle for threading. In use, the position of the spring hinge allows the tool to spring away from the work without digging in.

Forming Tools.—When it becomes necessary to machine a form a number of more or less irregular shapes on an engine lathe, turret lathe, or other machine of similar character, a forming tool of some sort is indispensible. When only a single piece is to be made, the operator can work out the shape a little at a time on an engine lathe to fit a templet of sheet steel which has been carefully laid out to the required dimensions.

There are many kinds of forming tools whose utility depends to a great extent on the class of work for which they are intended, as well as the number of pieces which are to be machined and the accuracy required in the finished product. The type of tool selected for any given piece of work, therefore, should be determined by these factors. For example, in the work shown at the upper part of Figure 41, a simple angular groove is to be cut on a lot of 500 pieces. It would be inadvisable, therefore, to go to any great expense in the matter of a forming tool. A rectangular tool, A, of some standard section should be formed to the shape shown at B with very little expense or trouble, and the work may be produced without difficulty. If such a tool as this, however,

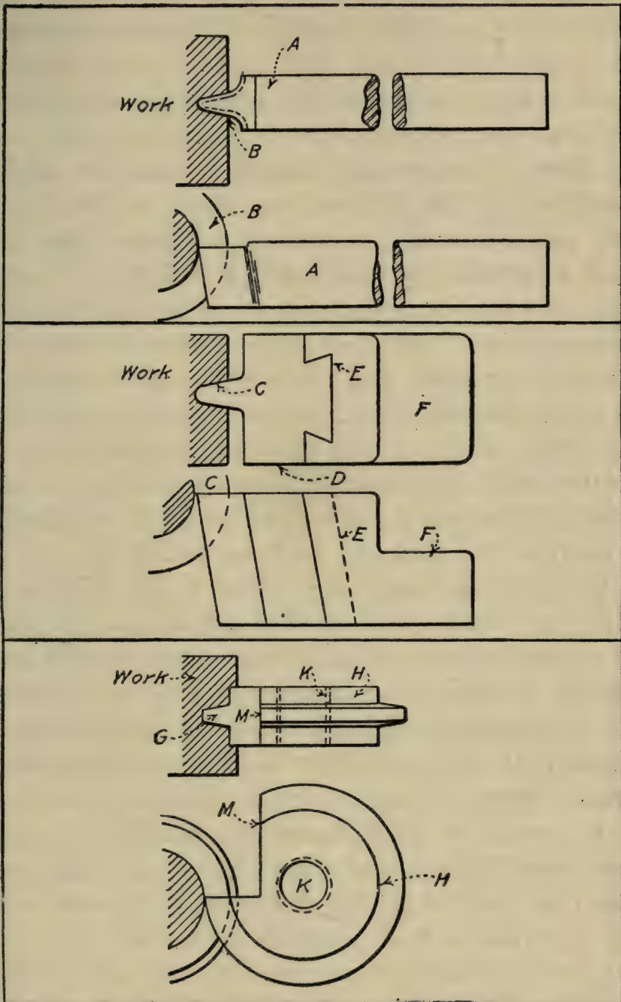

FIG. 41. THREE TYPES OF SIMPLE FORMING TOOLS

were to be used day after day and week after week, it would not give good results. Frequent regrinding would change the shape and size so that it would soon need to be replaced by another. This is due to the fact that the clearance as indicated by the dotted line is increasingly smaller than the part of the tool doing the cutting, so that as the face is ground away the tool becomes narrower and does not cut a groove of the desired width. To avoid changes in form caused by regrinding, an angularly set forming tool, such as that shown at C in the center of Figure 41 can be used to advantage. In this case a holder F, of special form is provided on the cross slide of the machine, bolted down in some approved manner according to the form of slide on which it is used. The holder is dovetailed at E to receive the forming tool on which the correct form, C, has been fashioned. The design of the tool is such that when it is ground flat across the front it will produce the required form. Clearance is taken care of by the angle at which the tool is set in the holder. Suitable clamping screws are provided in the holder so that as re-grinding is done adjustment can be made to keep the cutting edge always at the center line. In a tool of this character, which is required for very wide forms and heavy cutting, a set screw is sometimes placed in the holder directly under the tool to provide a firm support and take the thrust of the cut. When such provision is not made it may be found necessary to "shim" up the tool to prevent it from pushing down under the pressure of the cut. Tools of this kind are largely used on

turret lathe and screw machine work for producing various form and shapes up to four or five inches in length.

Smaller work, such as that on automatic and small hand-screw machines can be handled to advantage with the circular type of forming tool, H, shown in the lower part of Figure 41. This type is tapped out to receive a screw which passes through a special tool holder on the cross slide of the machine. If the holder is made for the rear of the cross slide, the center line of the screw, K, is from 1/8- to 1/4-inch below the center of the work. When the holder is designed to be used on the front of the cross slide, the center is about an equal amount above the work center, as indicated in the illustration. This arrangement is for the purpose of giving a greater clearance to the tool. It will be seen that a tool of this sort can be ground a great number of times and still preserve its form. Furthermore, it is a type not difficult to make, as it can be turned on an engine lathe to the desired form and then cut out, as at M, to give the cutting lip. Since the cutting edge of the tool is not on the center on which the turning of the tool is accomplished, a suitable allowance for this difference must be made when shaping it. Formulas for this type of tool can be found in "Machinery's Handbook."

CHAPTER V

MILLING AND PLANING

Milling Processes.—The process of milling a surface or form consists, essentially, in holding the work to be milled firmly and pushing it against a revolving cutter which removes the stock at a very rapid rate. The cutter is held in some approved manner in the spindle of a milling machine, or on an arbor, either in a vertical or horizontal position depending upon the nature of the work and the type of machine to which it is applied. Milling machines are of several fundamental types, each possessing features more or less distinctive according to the manufacturer and the particular class of work for which the machine is intended. Thus we have hand milling machines, plain milling machines, the Lincoln type of milling machines, universal milling machines, and so on, all of which are built with a horizontal spindle. Then there are vertical, rotary table, multiple spindle, duplex, and continuous milling machines, some of which have vertical spindles while others have horizontal spindles or even a combination of horizontal and vertical spindles on the same machine. In fact, the ramifications in these machines are somewhat difficult to keep in touch with from day to day on ac-

count of the many developments in rapid production processes.

Factors Influencing Machine Selection.—When any piece of work is to be machined by milling processes the proper machine to produce it most economically must first be determined. Next, having determined the machine to use, the method of holding the work must be considered and a fixture designed for it; finally the type of cutter to be used must be decided upon. Several factors have an influence on these points and are of great importance. They include:

1. Nature and composition of the material to be cut.
2. Size of the work.
3. Amount of metal to be removed.
4. Accuracy required.
5. Width and shape of cut.
6. Number of pieces to be machined.

It is obvious in considering the nature and composition of the material to be cut that for instance, a heavy piece of alloy steel would require a powerful machine in order to remove the stock to the best advantage, while a light piece of aluminum or brass could be handled more economically on a hand-feed or plain machine.

The size of the work also has an effect on the machine to be used, for it not infrequently happens that a light piece of work of large size must be machined on a heavy machine solely on account of the range required. In machining heavy forgings

of alloy steel, milling machines of great power must be used, and the fixtures in which the work is held must be of the most massive design in order to hold the work securely and prevent vibration or chatter.

The amount of metal to be removed affects the selection of the machine tool on account of the power needed to pull the cut. At the same time it influences the design and form of the milling cutter adapted to the work.

Speaking generally, surfacing cuts on castings are best handled by a face mill or end-milling cutter arranged to cut either horizontally along the side of the work, if used on a horizontal milling machine, or vertically on top of the work if used on a vertical-spindle machine. Steel work, on the contrary, can more profitably be handled with a spiral milling cutter, the cut being taken in a direction parallel with the center line of the axis of rotation. The accuracy with which a piece of work must be finished determines whether a single roughing cut will be sufficient or whether both roughing and finishing cuts must be taken. For the general run of work which does not require a high degree of accuracy, a single cut may be taken with success, but when interchangeable work within close limits of accuracy is to be manufactured it is usually advisable to take two cuts.

The width and shape of the cut determine both the class of machine to be used, the kind of cutters necessary, and the fixture required. In modern practice, a milling machine having both vertical and horizontal spindles is often selected for a piece of work of large size and the fixtures are designed so that several pieces

may be machined simultaneously. There are machines on the American market today having as many as seven spindles, all of which may be working simultaneously on a certain piece of work. Furthermore, the work may be roughed and finished in the same machine, one "bank" of cutters serving for the roughing cuts and the others for the finishing operations. Obviously, machines of this character are very expensive, but for high production work they are great money savers. Here it will be seen that the number of pieces to be machined is an important factor in regard to the type of machine used. Another point in this connection which should not be overlooked is the type of fixture which is used, but—this matter will be dealt with in greater detail under a later heading.

Milling Cutters.—The milling cutter, A, Figure 42, is an end mill of the ordinary variety with straight flutes. This type of cutter can be used for milling the edges of a surface on either a vertical or horizontal machine, and is provided with a taper shank to fit the milling machine spindle. The form, B, is of the center-cut type. It can be fed directly into the work if necessary, the teeth being so cut on the end as to permit this. With the type A, the form of tooth on the end does not permit such a cut to be taken.

The cutter, C, is an end mill of the same general type as that shown at A, except that the flutes are cut spirally. The cutting action on the side of this mill is better than that on the straight fluted mill, A, because the entire width of the flute is not all in

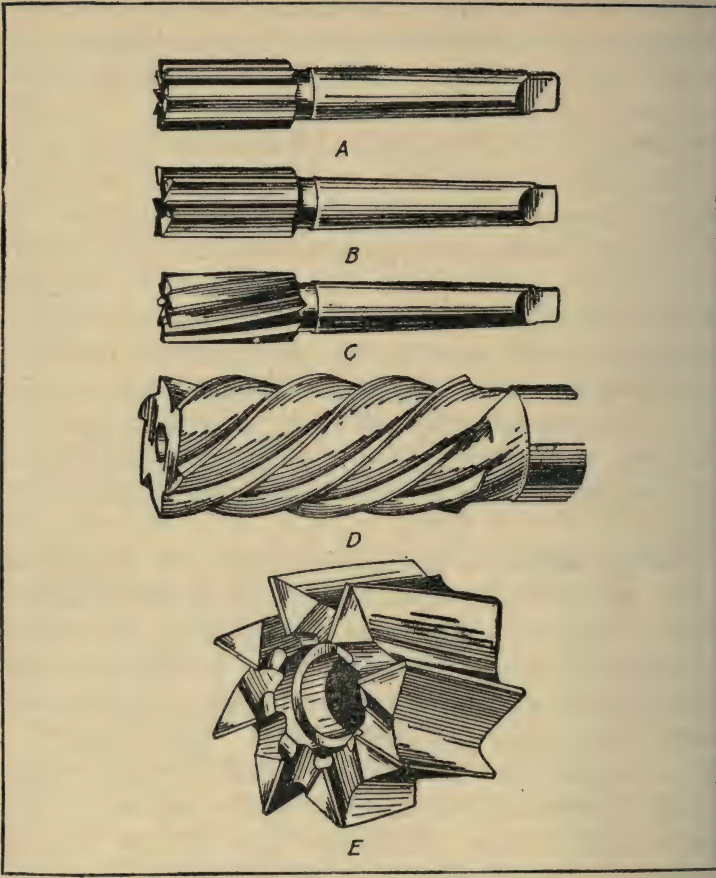

FIG. 42. GROUP OF STRAIGHT-FLUTE, SPIRAL, AND SHELL END MILLS

contact with the work at one time. The action, therefore, is a shearing cut instead of a pushing cut. This mill, also, requires less power to drive it and is less likely to produce chatter.

The special form of cutter shown at D is made on the same principle as that shown at C, except that it is intended to cut only on the side. The spiral in this case is much more abrupt, so that the shearing action is very pronounced. A cutter of this kind gives excellent results on steel and produces a superior finish by virtue of its shearing cut. The flutes may be nicked to break the chip; this makes the cutting action easier and is an advantage on very tough and wiry material.

When an end mill of a greater size is required, it is evident that it would not be economical to make both tool and shank of high speed steel; hence the shell end mill, E, has been devised. It can be seen that such a mill is easily attached to a stem or tapering arbor which fits the conical hole in the mill. The end of the arbor is threaded so that the mill can be forced back onto the taper by means of a nut applied to its face.

Shell end mills are made in a variety of ways to suit different conditions; in the larger sizes, for instance, the body of the tool may be made of cast iron or steel with the cutter blades inserted. When inserted blades are used it is evident that the cost of upkeep is much less than when the mill is cut from the solid metal, for a broken tooth can be readily replaced with a new one; furthermore, an entirely new set of blades can be substituted for a worn out set at comparatively small expense. Ordinarily, mills up to five inches in diameter are made from a single piece of high-speed or carbon steel, while those above this size are made with inserted blades.

Slotting Cutters.—If a straight slot, open at the ends, is to be cut in a casting or other piece of work, a plain end mill such as that shown in Figure 42 at A or B can be used. But if the slot is I-shaped, another type of cutter, A, Figure 43, must be used.

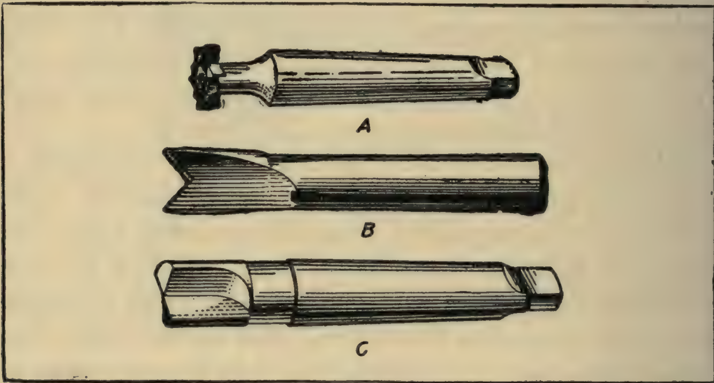

FIG. 43. (A) TEE-SLOT CUTTER. (B) FISHTAIL CUTTER (C) TWO-LIP SLOTTING CUTTER

This cutter is commonly spoken of as a tee-slot cutter. It will be noted that the neck of the tool is smaller than the cutter, so as to permit under cutting the work, or getting the tool down into a slot, etc. This same type of cutter is also used for cutting the circular slot in a shaft when a Woodruff key is to be inserted.

In many kinds of manufacturing work it is necessary to cut a narrow slot with rounded ends, as for example a slot, or "spline" as it is more frequently called, in a shaft in which a key of rectangular section is to be fastened to act as a driver for a pulley or a gear. There are several ways to cut such a

spline, but such cutters as shown at B or C, Figure 43, are most useful. The cutter, B, is termed a fishtail cutter from its resemblance to a fish's tail. The cutter, C, is a two-lip slotting cutter or routing cutter. Both types are used for the same work, but the latter is used more frequently on cast iron to cut directly into a piece of work to the depth desired; then the work is fed along to the required distance. The fishtail type is more useful for steel work since it has better chip clearance. These tools are commonly used on the spline-milling machine or on a milling machine with a spline-milling attachment for cutting slots and splines in general manufacturing work.

Angular and Special Cutters.—Various types of cutters have been developed for different kinds of work, the shapes being dependent upon the form to be cut and the manufacturing conditions governing the production. In making up reamers, drills, and special tools of different kinds, special cutters are a necessity in developing the required forms. Referring to Figure 44, the sectional views shown at A and B indicate respectively the shape of the cutting edges of the milling cutters used for cutting flutes in reamers and taps. C and D are used for fluting twist drills and other work of similar character. F and G are respectively single and double angle cutters used largely for cutting spiral mills or other work when one or more of the surfaces to be milled lies at an angle to the axis of the work. E, H, and K are cornering, concave, and convex cutters respectively. They are used for a variety of purposes on special

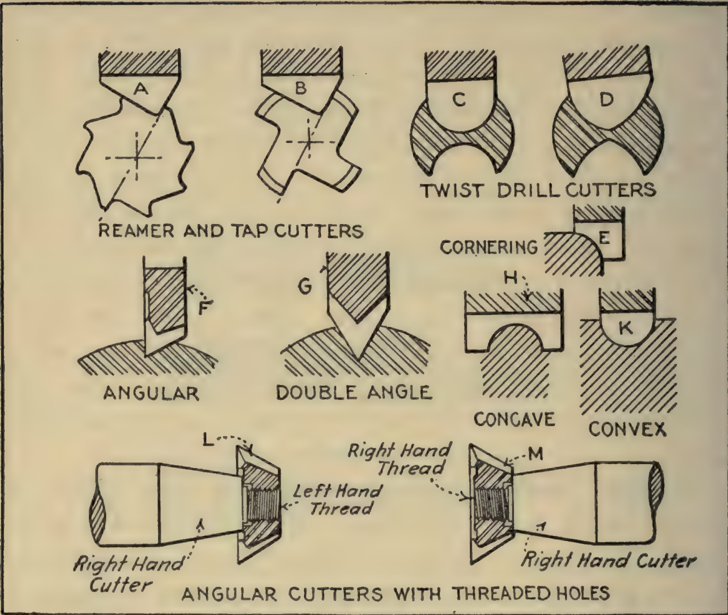

FIG. 44. ANGULAR AND SPECIAL TYPES OF MILLING CUTTERS

work, the radii of the cutters being made up to suit any particular piece of work for which they are to be used.

When a piece of work is to be machined which does not permit a cutter to be held on an arbor extending on both sides of the cutter, it may be necessary to make up the types shown at L and M. It is obvious that as such a cutter must be screwed on to an arbor, as indicated, it must have either a right-hand or left-hand thread according to the direction of rotation of the spindle. These cutters can be made up in any form to suit the class of work on which they are to be used.

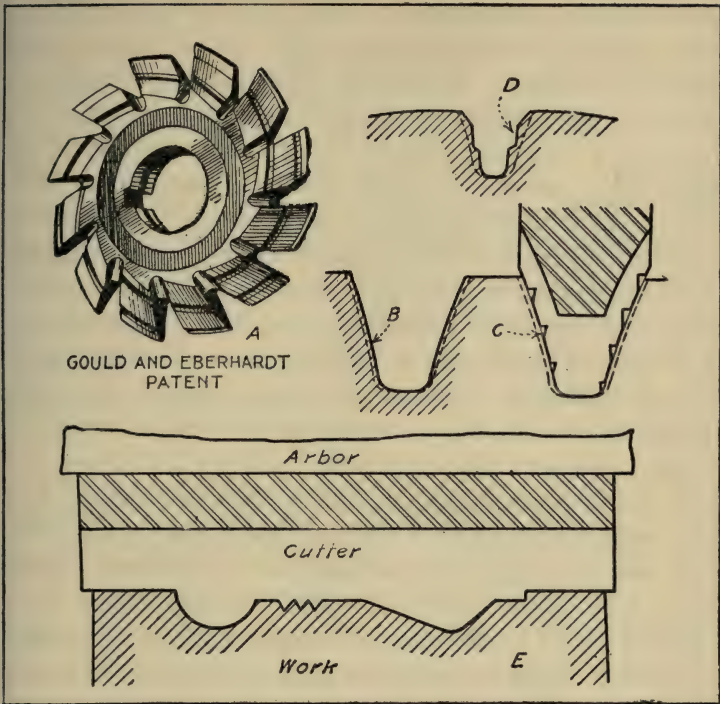

FIG. 45. GEAR-TOOTH CUTTERS AND FORMED CUTTERS

Gear-Tooth and Formed Cutters.—In cutting the teeth in spur gears the cutter, A, Figure 45, is frequently employed. This cutter, patented by Gould & Eberhardt, Newark, N. J., is so made that each tooth is of slightly different form than the one preceding it and progressively removes metal left by the preceding tooth. The value of this method of cutting lies in the fact that the stock as it is removed is broken up into a great number of small chips instead of a comparatively small number of wide chips.

The obvious advantage is that the cutting action is much easier and it requires less power than other forms of cutters. With this type, used for roughing only, the gear tooth is cut to its correct shape, leaving only a small amount to be removed by the finishing cutter, as shown at B in the illustration. The manner by which the chip is broken up by the cutter is indicated at C. The ordinary type of roughing-out or stocking cutter for gear teeth is of somewhat similar shape, but it makes a cut like that shown at D, Figure 45, which, it will be seen does not leave an equal amount of stock all around for the finishing cutter to remove, for this reason it is not as effective in its work as the other type.

In some manufacturing work unusual shapes may be required cut from a flat surface or strip of metal, and when the quantity demanded is sufficient to warrant it the form can be milled to advantage by a cutter formed to the correct shape, as indicated at E, Figure 45. Let us suppose that a number of blocks are to be made from blocks 2 inches long to have a form like that indicated. In order to produce a number of pieces of this kind it is only necessary to make up a cutter of the required form and to mill a number of long strips on the milling machine. The strips can afterward be sawed up into short pieces each of which is 2 inches long.

All milling cutters are "relieved" at the back of the tooth, in order to provide chip clearance for chips removed from the work by the cutting action and also to prevent the back of the tooth from rubbing on the work during the operation. Formed cutters

like the one shown at D, however, are given a different kind of relief, called an eccentric relief, which permits the cutter to be re-ground a number of times after it becomes dull without changing the shape of the piece milled.

Miscellaneous Cutters.—It is obviously impossible to describe and illustrate every type of cutter without entering into a lengthy discussion of the subject of milling. Such a discussion is unnecessary here. The descriptions show that varieties to meet every condition can be made. Figure 46 shows a group of common cutters used for various purposes in the average factory. The cutter, A, is generally termed a "hob." It is used for milling the teeth in a worm gear, the work being held on an arbor either on a milling machine or a gear hobber. In making such a cutter the shape first produced is very similar to a worm gear and the teeth are formed by cutting longitudinal grooves. Each of the teeth is then relieved, and the cutter is hardened and ground ready for work. A hob cutter, when used for a worm gear, must always be made up specially for any piece of work. Gear teeth of the spur variety, however, are cut with so-called generating hobs on regular gear-hobbing machines, which can be bought in stock sizes according to the pitch of the teeth and the kind of machine on which they are to be used. Each hob, however, is made for a specified pitch of tooth and can be used only for this pitch.

In this connection an amusing incident occurred some years ago in a New England factory where there were a number of apprentices. One of the ap-

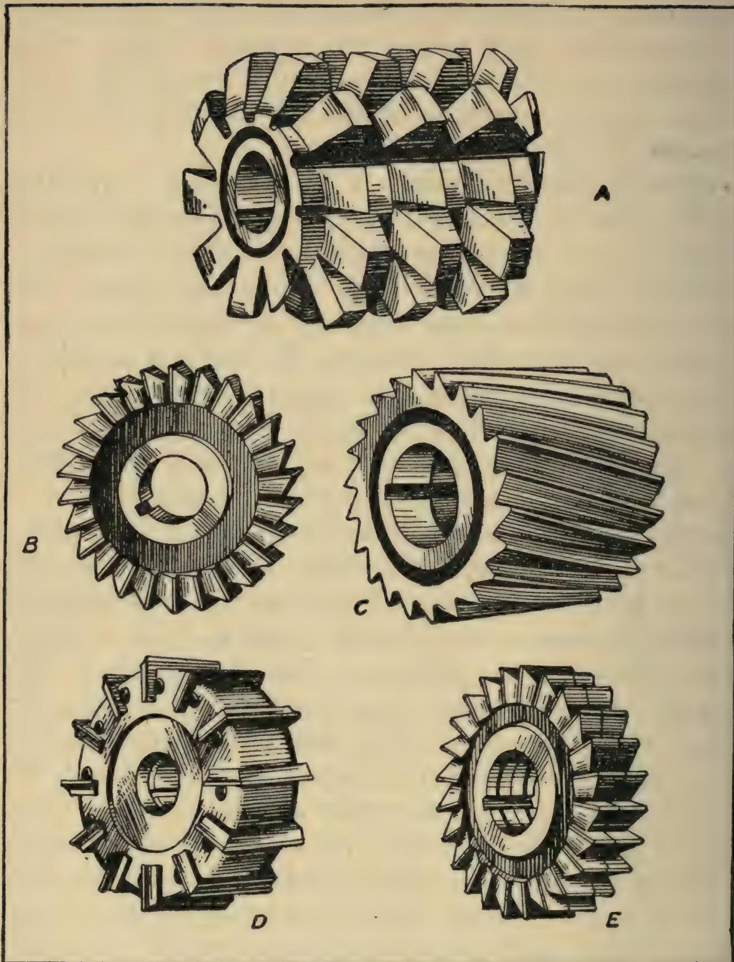

FIG. 46. (A) WORM HOB CUTTER. (B) SIDE OR STRADDLE MILLING CUTTER. (C) PLAIN MILLING CUTTER. (D) INSERTED-BLADE CUTTER. (E) INTERLOCKING MILLER CUTTER

prentices was sent to the tool room by the tool maker for whom the boy was working, who told him to get "the hob used for the big gear on Machine No. 1272." On the way to the tool room the boy forgot the number of the machine, but nevertheless he asked the tool crib man to "give me a hob for a big gear." "What machine is it for?" the man asked him. "Oh, I don't remember the number of the machine, but you better give me the biggest one you've got 'cause it's a big gear." Needless to add, he was told to "beat it, and get the machine number."

The cutter, B, Figure 46, is a side-milling cutter used as a single cutter for side milling or for facing a piece of work. It is also frequently used in gangs of two or more spaced the required distance apart for "straddle milling." For example, if a boss on the end of a lever needs to be faced on each side, two side-milling cutters would be properly spaced on an arbor in the milling machine so that the distance between the cutters would be the same as the width of the finished boss on the lever. Given the proper kind of fixture for holding the work, then, a great number of pieces could be machined one after the other with perfect uniformity until the cutters were so worn as to require readjustment.

For heavy work of large diameter inserted-tooth facing-mills, D, Figure 46, are used both singly and in groups for the same purpose as the side cutter, B. Cutters of this kind are largely used for making heavy facing cuts on both cast iron and steel. They will also produce good results on aluminum or brass. On vertical milling machines and multiple spindle

machines this type of cutter is extensively used for general manufacturing.

The plain milling cutter, C, is intended only for surfacing or milling broad flat surfaces. It is most frequently used for milling steel. Frequently this cutter is set up with two or more side-milling cutters to mill a flat surface and at the same time to straddle mill both sides. It will be noted that the teeth on the cutter are milled spirally in such a way that as the cutter revolves each tooth engages the work progressively with a shearing cut, thereby producing a very fine finish with little likelihood of chatter. It is well to state at this point that no matter what style of cutter may be used on any piece of work some chatter may result. Loose gibbing (loose attaching) on the table of the machine is a frequent cause, the remedy for which is apparent. Another cause is a poorly designed fixture for holding the work or an inefficient method of clamping the work in the fixture. Still another is the use of an incorrect speed or improper feed, or a combination of both, which will be discussed in a later chapter.

Interlocking Cutters.—In many processes of manufacturing occasions arise when it is necessary to mill a slot in the work to a specified size within close limits of accuracy. The ordinary type of side-milling cutter, B, Figure 46, if used for this work soon becomes so worn on the sides that, after grinding a few times, it is a trifle under size and does not cut the slot to the required dimensions. When such a condition as this arises, therefore, an interlocking cutter, E, Figure 46, should be used. This illustra-

tion shows that the cutter is really a double cutter, made up of two parts which fit into each other in such a manner that every other tooth laps over an imaginary center line drawn around the circumference of the cutter. By this arrangement the teeth of the cutter may be adjusted by placing a disc of thin paper between them when they become slightly worn, the paper disc being made thick enough to compensate for the wear caused by hard usage and frequent regrinding. Such a cutter can be kept up to accurate size, and will always produce a piece of work within the required limits.

Planing Tools.—Surfaces requiring the greatest accuracy are often planed instead of being milled. This is particularly the case with heavy castings such as machine beds and heavy fixtures, or parts of machines which are a sliding fit on each other—such as the cross slide on a turret lathe, the carriage on an engine lathe, the table of a milling machine and other work of similar character. In large manufacturing work—the building of locomotives, steam engines, compressors, or printing presses—the planer is a valuable adjunct; but for smaller manufacturing the milling machine is much more largely used, not only on account of its superiority in the matter of rapid production but also because it does not require so experienced an operator as the planer.

The tools used in planing are generally single forged tools of a nature similar to those used on the engine lathe. There is a little difference in the shapes of the tools, however, since in the one case the work is revolving, while in the other the work is moving

along in a horizontal direction. Except for the fact that planer tools are somewhat heavier than lathe tools, there is so little difference in them that it is rather unnecessary to go into an extended description of them. It should also be remembered that the planer is not used to any great extent in interchangeable manufacture, so that the tools are not so highly specialized but, more frequently, are ground in a slightly different way to suit the particular case.

CHAPTER VI

BROACHING

The Purposes of Broaching.—The process of broaching holes, either round or rectangular, is by no means new, but modern methods differ from those in use a few years ago. In present-day practice the broach is pulled through the hole as a rule, while the former method favored a pushing action in forcing the tool through. Strictly speaking the broaching of a hole is a shaving operation produced by a number of cutting edges on a tool of suitable form. The teeth on the broaching tool are so arranged that progressively they come in contact with the work as the tool is forced through. Each tooth is set out beyond the preceding one a few thousandths of an inch, the amount being dependent upon the length of the broach, the kind of material which is being cut, and the amount of stock which is to be removed.

The design of broaches therefore must take into consideration the points mentioned and also the matter of upkeep—re-grinding and replacement when worn. For example, it would not be economical to design and make up a broach which was to be used only for a couple of hundred pieces in as painstaking a manner as though the work consisted of several thousand pieces. It would be the part of wisdom to

make up the tool as cheaply as possible consistent with good workmanship; but if several thousand pieces were to be broached refinements in design could be made so that replacements could be made as easy as possible.

Preliminary Treatment.—The preliminary requirements in broaching a hole are that the work shall have been previously drilled or bored, or that an opening of some sort in the piece is large enough to permit the entry of the small end of the broaching tool. It is also necessary to ensure that the work can be properly held and so located that the broaching operation will be done in the correct location on or in the work. Sometimes a previously drilled or reamed hole can be used for locating the work precisely by slipping it onto a stud on the face plate of the machine. In some cases the broach itself acts as the locating medium.

In order that the process of broaching may be more readily understood by the reader, let us assume that a gear blank has been drilled, bored and reamed, and that it is desired to cut a keyway through it, as in X, Figure 47. In this case the face plate of the broaching machine is provided with a "pull-bushing," as it is called, in which a slot is cut to allow the broach, A, to pass through it. This pull-bushing then acts as a guide for the broach and at the same times locates the work properly for the operation. This broach, A, is called a "keyway" broach and may be purchased cheaply in standard sizes from the makers of broaching machines, or it may be made up in the tool room of any factory at comparatively

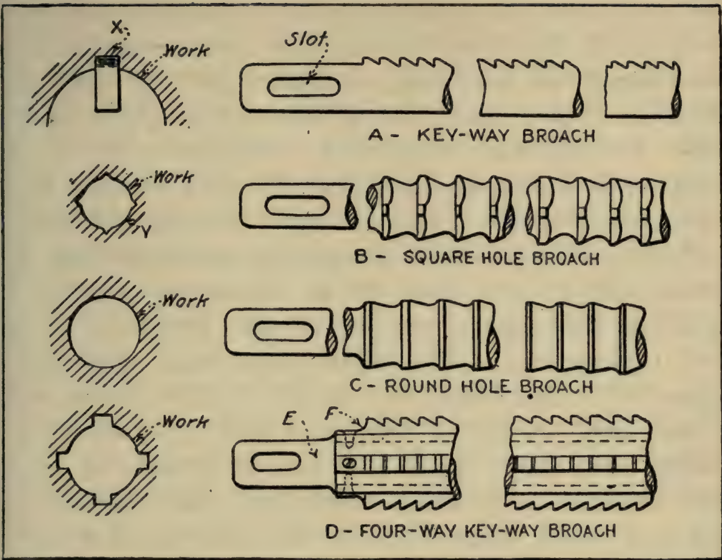

FIG. 47. SEVERAL VARIETIES OF BROACHING TOOLS

small expense. One end of the tool is slotted, so that a pin can be used to couple it to the feed-screw mechanism of the machine. The teeth on the broach, starting at the end where the slot is, are graded in such manner that the first tooth cuts a very shallow groove in the work, the next tooth increases the depth slightly, and the remainder of the teeth act in like manner progressively. The last four or five teeth in the broach cut the full depth of the slot, for the purpose of assuring the accuracy of the work in the event that some of the teeth become worn.

Broaching a Square Hole.—As a broaching cut of any kind requires a powerful machine, it is evident that the wear on the broach is very severe. There-

for to relieve the machine as far as possible and also to provide for long life in the broach itself, it is customary in broaching a square hole to drill the work out previously to a diameter slightly larger than the distance across the flat surfaces of the square, as shown at Y, Figure 47. The broach, B, is the type used for a square hole. The slotted end is cylindrical and a trifle smaller in diameter than the previously reamed hole so as to act as a pilot in guiding the square portion of the broach into the hole. Broaches of this variety are made of a single piece of carbon steel, machined to the shape indicated, and carefully hardened and ground before being used. The teeth also cut progressively as in the instance previously mentioned, the amount cut by each tooth being slightly in excess of that taken by the tooth just ahead of it.

In broaching steel, the teeth of the broach are usually well lubricated at the moment before they enter the hole, thus reducing the friction of the cut and carrying away the heat generated. The proper lubricant is determined by the material which is to be cut. The various important matters connected with the subject of lubrication, however, will be found in Chapter XIX.

Broaching a Round Hole.—Formerly, the proper method of obtaining a cylindrical hole to a given dimension was by the reaming process. The ordinary procedure was to bore the hole with roughing and finishing boring tools, leaving a few thousandths of an inch of metal to be removed by the reamer. Recent developments, however, have shown that a

round broach can be used to better advantage. The finish in the hole produced by a broach is superior to that made by a reamer, and the required size can be easily obtained. In the matter of upkeep, also, the broach is superior to the reamer, although its first cost may be somewhat higher. As to accuracy, the modern broaching machine can be fitted with fixtures for holding the work and locating it so exactly that center distances can be precisely maintained. As a matter of fact the broaching process may be considered as a precision operation.

When it is desired to broach one hole in a piece in a definite relation to another, it is only necessary to locate a stud on the face plate of the machine at the proper distance from the center hole and provide a broach of suitable form. It will be understood that when the hole is a single one and not located accurately with relation to some other one in the work the broaching machine centers the broach in the work by the previously reamed or bored hole. In such a case no special fixture is needed.

In the case illustrated in Figure 48, a very accurate location is necessary between the two centers, A and B, in the work, C, an automobile connecting rod. Prior to the operation shown, the hole, A, has been drilled and broached to the proper size, no fixture being used in the operation and the hole itself acting as a locating point. For the operation shown the work is located on a stud on the face plate by the hole, A, which is located the correct distance from the other hole, B, the latter being the center line of the broach itself. For work of this nature the broach-

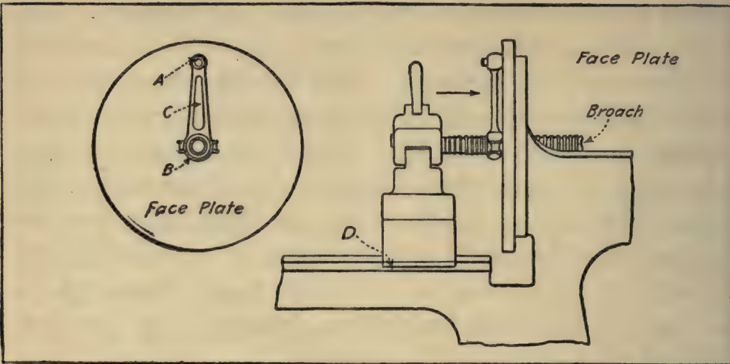

FIG. 48. METHOD OF BROACHING A CONNECTING ROD

ing machine must be furnished with supplementary equipment in the nature of a support table and slide as indicated in the illustration. The slide, D, supports the end of the broach and centers it correctly as it is pulled through the work. Most excellent work can be done with such equipment. The broach, C, Figure 47, is used for round holes, and differs from B only in shape. Naturally the teeth are formed by a series of progressive rings instead of squares.

Four-way Keyway Broaches.—In automobile and machine tool work it is sometimes necessary to cut four keyways in a piece of work which may be either a sliding fit or a close fit on a shaft, four keys being set into it for the purpose of providing an efficient method of driving. When such a broaching job is to be done the broach is made up in a somewhat different way than those previously described. In Figure 47, D, the cutting blades, F, are made up separately and are fitted to the body of the broach, E, by some approved method, such as the screws indicated

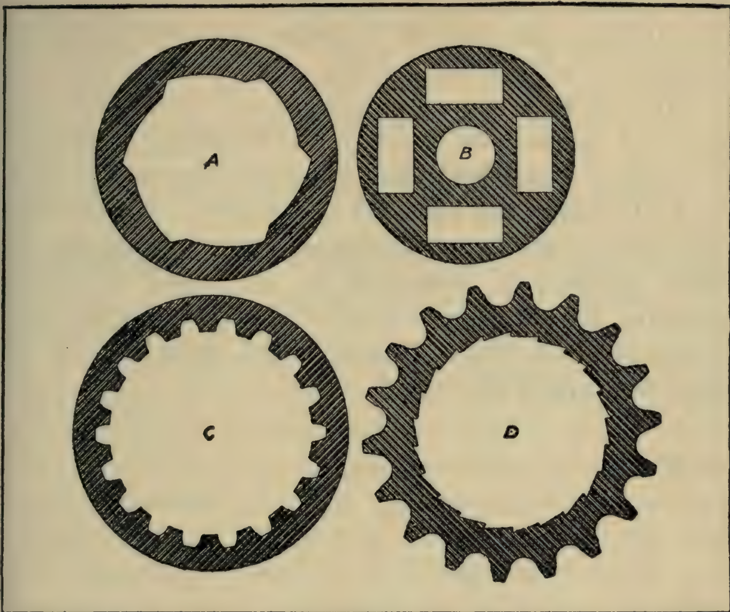

FIG. 49. EXAMPLES OF IRREGULAR HOLES THAT CAN BE BROACHED

in the drawing. Other methods of fastening are also used, and, generally speaking, a method should be adopted which permits adjustment and holds the blades firmly.

Broaches For Irregular Holes.—Irregular forms, such as internal gears of some kinds, ratchet teeth, and many other varieties of holes, can be broached to advantage providing that the production is large enough to warrant the necessary expense of procuring the broaches. A few shapes which can profitably be broached are indicated in Figure 49. The form, A, is an internal cam, ½-inch thick, made of steel. Sev-

eral of these pieces are generally broached at one time without the use of a fixture, the broach being formed to the required shape. The form, B, is out of the ordinary and serves to show the variety of work which can be done on a broaching machine. The four rectangular holes are made concentric with the center hole, the material being steel. An internal spur gear is shown at C, and a sprocket with an internal ratchet is indicated at D. Both of these broaches are of the solid variety, formed to the correct shape and the teeth cut in the same manner as those previously described.

CHAPTER VII

SURFACE AND CYLINDRICAL GRINDING

Grinding Material.—Many persons take an erroneous view of the process of grinding and consider that it is adapted only to the truing up of parts which have been hardened and which, therefore, cannot be cut by the ordinary type of tool. As a matter of fact the up-to-date factory employs grinding for many parts which have not been hardened at all. When parts have been hardened they are likely to be more or less distorted and out of true, and these distorted parts can be corrected by grinding with a wheel composed of emery, carborundum, alundum, or other abrasive.

Many of the compositions used for making grinding wheels are produced by artificial means, but the chief natural abrasives are emery and corundum, the latter being used to a greater extent than emery. The abrasives produced artificially are composed principally from carbide of silicon and bauxite fused at a high temperature in the electric furnace. The various trade names of the artificial abrasives and their composition and uses are as follows:

Adamite is used in wheels for grinding materials such as steel either soft or in a hardened state. It is an artificial abrasive made in Austria, and is com-

posed of aluminum oxide with certain other materials fused together in an electric furnace at a high temperature.

Aloxite is used in wheels for grinding the same class of materials as that mentioned above. It is a product of the Carborundum Co., and is made by a special process from aluminum oxide crystals produced by fusing mineral bauxite in an electric furnace.

Boro-carbone is a trade name for another product of bauxite, as manufactured by the Abrasive Material Co. This abrasive is used for grinding materials which possess high tensile strength.

Carbide of Silicon is used for grinding brass, cast iron, and other materials which possess low tensile strength. It is a composition of coke and sand fused in the electric furnace. This material also is a product of the Abrasive Material Co.

Carbolon is used for materials having a low tensile strength. It is made by the Vitrified Wheel Co., from coke and sand fused in the electric furnace.

Carborundum is a very well known abrasive which is a chemical combination of carbon and silicon fused at a temperature of 7000 degrees Fahrenheit.

Crystolon is an artificial abrasive made by the Norton Co. It is particularly suited to the grinding of cast iron, brass, and other materials of low tensile strength. The chief ingredients of this abrasive are carbon and silicon.

Corundum is a mineral derived from native alumina and is the purest of all the natural abrasives. It is also produced by artificial means in an electric fur-

nace and, next to the diamond, it is the hardest of all known materials. In reality it is nothing more than crystallized aluminum oxide, whether obtained by either natural or artificial means. The artificial product can be obtained in many grades suited to many varieties of work.

Emery is used for obtaining a fine finish on bearing surfaces, ball races, and the like; but as an abrasive in manufacturing grinding processes emery has been largely superseded by some of the other materials mentioned in the foregoing list. While it is unexcelled for certain kinds of work, it does not possess the hardness nor does it have the free cutting qualities of some of the other abrasives.

Grinding-Wheel Shapes.—Grinding wheels are made in a variety of sizes and in shapes of every kind for cylindrical work, shouldered work, forming, internal work, surfacing, and so on. Some of the more common forms are shown in Figure 50, although these are but a very few of the many kinds and forms in use. In selecting a wheel shape for any piece of work, it is obvious that several things must be considered—the kind of machine to be used on the work, for instance, or the form to be ground, or the method of presenting the wheel to the work itself. So many factors affect the shape of the wheel to be used, in fact, that it is out of the question to illustrate and describe the various kinds in a work of this kind; moreover such a description would be of no material value to an executive for it would entail so great an amount of descriptive matter as to be confusing rather than enlightening. For the specific cases of

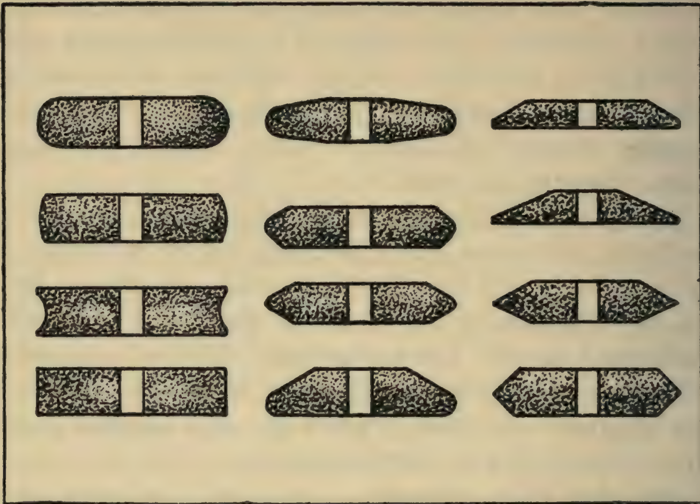

FIG. 50. VARIOUS SHAPES OF GRINDING WHEELS

grinding illustrated in this book the style of wheel shown in any particular case may be considered as the ordinary shape used for the work.

Surface Grinding Methods.—When a plane surface which has been hardened or which, unhardened, needs careful finishing, it is frequently desirable to grind the surface to the required finish. Some machines which are used for surface grinding are adapted principally to light work requiring a high degree of accuracy, such as die blocks and other tool room work, while others are intended for general manufacturing. When work is to be ground on a surface grinder it is of the highest importance that it should be held in such a way that there can be no "spring" or distortion arising from an improper method of clamping. Magnetic chucks—that is, magnetized

plates—are largely used for holding work which is to be finished in this way, although there are cases which require some more positive clamping action. The description of fixtures for holding work during grinding operations is dealt with in Chapter XVI.

Several methods can be employed when a piece of work is to be finished accurately to a plane surface, and the one selected depends only upon the accuracy required in the finished product. Thus for a moderately good commercial job, two milling cuts—one roughing and the other finishing—may be taken with satisfactory results; this method is suitable for comparatively narrow surfaces, such as the flanges on a transmission case in automobile construction or other work of similar character. For the surfacing of a machine bed or the finishing of the plane portions of locomotive cylinders, the planing operation will be most suitable. But for accurate die work and for gauges and the like a surface grinding operation or even a lapping operation* may be necessitated. Also for many operations in general manufacture where surfaces require a high finish within very close limits, the surface grinding operation offers many inducements; for example, in the finishing of rifle hammers over a hundred pieces may be laid on a magnetic chuck and ground both accurately and quickly.

* Lapping is not usually a manufacturing process. Primarily it consists of rubbing two surfaces—cylindrical or plane—together—with an abrasive such as flour emery between the surfaces. Fine gages are lapped to produce absolutely accurate work. Lapping is a hand operation and does not enter into the ordinary processes of manufacture.

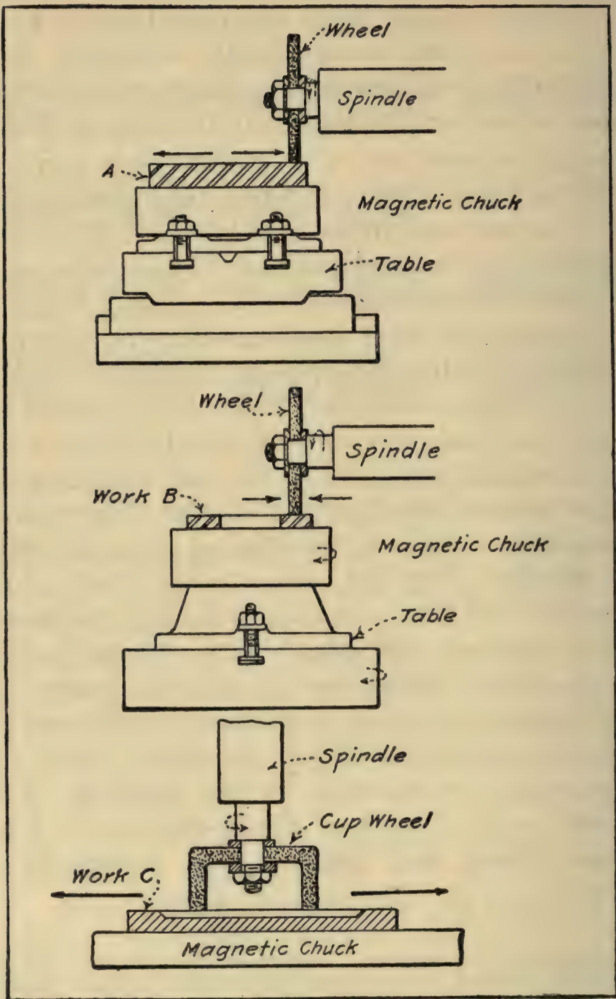

FIG. 51. SURFACE GRINDING METHODS

Referring to Figure 51 the upper illustration shows a piece of work, A, with a flat surface, such as a die, which is to be ground after it has been hardened. In such work a machine having a horizontal spindle is employed and a thin wheel is used. The work table reciprocates—moves back and forth—under the wheel and feeds transversely at the end of each stroke, so that the entire surface of the work is ground in a series of parallel cuts. The wheel spindle is so arranged that it can be raised or lowered by a screw with micrometer adjustment, thus very accurate work is easily produced. Strictly speaking, a piece of work which is to be ground on this type of machine is more often found in the tool room than in general manufacturing, although the machine can be adapted to certain classes of high-grade manufacture.

The work, B, gives an excellent example of grinding, the work involved being a cast iron ring which is to be accurately ground to a uniform thickness. In this case also a magnetic chuck is used to hold the work and a rotary table is employed. The spindle of the machine moves back and forth over the surface of the ring as indicated by the arrows in the illustration. The wheel used for this class of work is similar to that used in the previous example, and also this kind of grinding is used principally with work which has been previously finished to within a few thousandths of an inch of its required size. It is well suited to the finishing of packiing rings for steam engines, automobiles, compressors, and the like.

For heavier manufacturing and more severe cuts on larger work, a machine of a different type is more

frequently used, which has the spindle nearly vertical but with a very slight inclination to provide for clearance behind the cutting edge of the wheel. In an example of this kind, it will be noted that the wheel is shaped like a cup, usually called a cup wheel. The work, C, may be held on the table of the machine by means of a magnetic chuck or by clamps, depending upon its shape and the material from which it is made. For long work a machine having a reciprocating table is often used, and it is often possible to have several pieces on the table at the same time. For this kind of grinding the wheel should be of sufficient size to cover the entire width of the work. The speeds and feeds at which different kinds of grinding are done will be considered in Chapter XX.

Cylindrical Grinding.—In cylindrical grinding the work is frequently held on centers when it is of such a nature that one end can be dogged* for the purpose of driving. But it is not always that centers can be used on cylindrical work, and the chuck is frequently used for the purpose. In such cases it is of extreme importance to arrange the holding device in such a way that it will not distort the work. As in surface grinding the pieces to be ground may have been hardened previously or they may be soft, but in either event the operation of grinding and the method of presenting the work to the wheel are identical.

The shape of the wheel used for cylindrical grind-

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* A dog is a simple sort of clamp used for cylindrical work to act as a means of driving. Several types of dogs can be found in every machine shop. Dogs are usually provided with a setscrew to hold the work firmly and a tail which enters a slot in the faceplate and acts as a driver.

ing is usually like that shown in Figure 52 at A, although variations of the shape occur to suit different conditions. Let us suppose, for example, that a piece of work of cylindrical shape is to be ground, and that at the end of the ground surface there is a "fillet" which is also to be ground. In such a case the wheel which would come in contact with the fillet would be

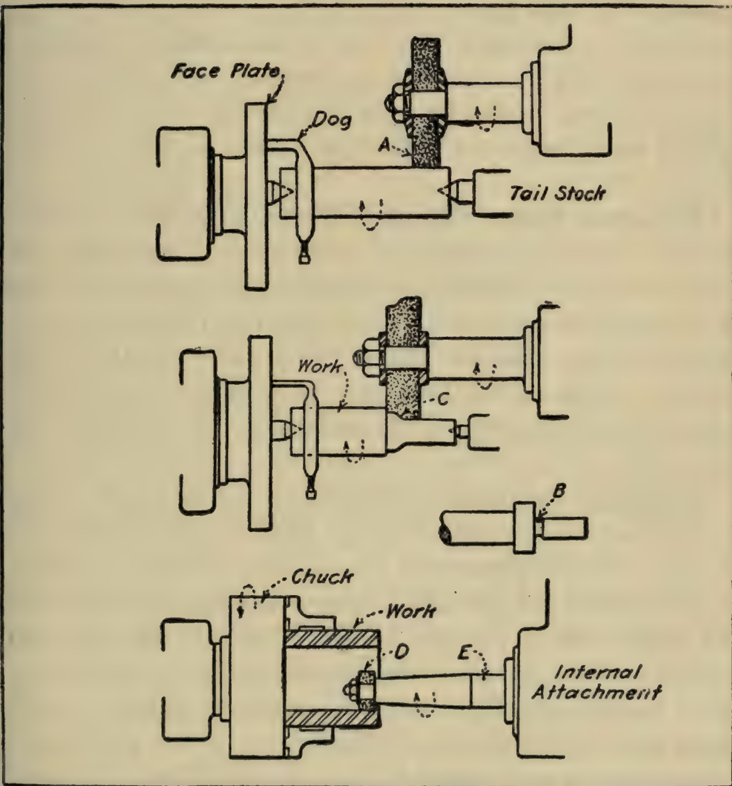


FIG. 52. CYLINDRICAL AND INTERNAL GRINDING METHODS

so shaped that it would finish the form at the end of the stroke.

If there are several diameters to be ground and a great number of pieces are to be finished, it is common to make a separate operation for each diameter. The reason for this is that the diameter stops and indicating dial on the machine can be set for repetition work to better advantage if a single diameter is handled at one time.

When cylindrical work is to be ground up to a shoulder and leave a sharp corner, it is customary to provide a nick close to the shoulder so that the wheel can "run out" at this point, as shown at B, Figure 52.

External Taper Work.—When a piece of taper work is to be ground the process is practically the same as for straight cylindrical work, except that the machine carriage is swung to the proper angle to generate the correct taper. The form of the wheel is the same as that shown at Figure 52, and the method of dogging and centering the work is also the same.

External Form Grinding.—For some work where a form of a prescribed shape is to be ground on the outside of a cylindrical piece, the wheel is fed directly into the work until the proper depth is reached, as indicated in Figure 52, C. The process of form grinding has lately been developed to a great extent in the grinding of such forms as shrapnel, rifle barrels, and other forms which have to do with munition-making and small arms. In grinding a shrapnel shell, for example, the wheel for one operation is

formed to take the curve on the end of the shell, while in the operation of grinding the straight portion of the body a wide wheel is used for one portion and a narrow wheel on another part. In grinding rifles, the barrel is usually ground at an approximately central location on the length of the barrel to provide a smooth surface for the steady-rest; the tapers are then ground with a formed wheel according to their variety and shape, and the cylindrical surfaces are handled in the usual manner. If there are any tapered surfaces on the barrel, these may be either ground with a formed wheel or the grinding-wheel carriage can be set over to the required angle for generating the taper.

Internal Grinding.—The process of internal grinding is applicable to either straight or tapered surfaces, but the work must be performed with an internal attachment, such as that shown at E, Figure 52. The wheel, D, in this case is of much smaller size than the type of wheel used for external grinding, although it is practically the same shape. The process of internal grinding is particularly useful in the making of bearing bushings and other work of similar character. The work may be either straight or tapered; both kinds can be handled with equal facility providing that the angle of the taper is not too great for the carriage to accommodate it.

In the example shown, the work has been previously machined and a sufficient allowance has been made for grinding before the hardening operation. The work is held in a special form of chuck as indicated, and the wheel, D, passes back and forth in the

work until the desired diameter has been ground. Suitable adjustments for diameter can easily be made on the machine, and it is entirely possible to keep manufacturing work within a limit of 0.00025 inches on the diameter. Many varieties of chucks are used for this class of work and some of these are of particular interest in the provision made for locating, holding, and driving the work without distortion. These will be dealt with more specifically in Chapter XVI.

Cylinder Grinding.—In automobile manufacture, and also in the manufacture of compressors and other work of this kind, the process of grinding the inside of the cylinders is extremely important. For this purpose a cylinder grinding machine has been developed by the Heald Machine Co., which operates on a different principle from those used in ordinary internal cylindrical grinding. It may be noticed that in the preceding example of internal grinding, the work revolves around its own center and different diameters are ground by re-setting the wheel spindle. In the Heald cylinder grinding machine, however, the work is so arranged that it does not revolve but the wheel spindle is given a double movement—that is, a rapid turning movement of the wheel on its own center and an eccentric rotary motion of the spindle itself. The spindle is so arranged that it can be set sufficiently eccentric to the center, within the capacity of the machine, to describe a circle equal to the diameter to be ground. Pieces such as an automobile cylinder, especially cast "en bloc," can be arranged on the carriage of the machine so that one hole can

be ground to size and the carriage set over the correct center distance to grind the other cylinders. Other data in regard to the grinding of automobile cylinders will be found in Chapter XVI, Grinding Fixtures.

CHAPTER VIII

SHOP EQUIPMENT

Standard Equipment.—Any factory which is intended to produce work at a minimum expense must be properly equipped in its various branches. The tool crib must be well supplied with all standard sizes of drills, counterbores, reamers, boring tools, taps and dies, and all the other implements which may be assumed to be a part of the tool crib equipment. Such tools as milling fixtures, drill jigs, boring fixtures, and the like, also form a part of the equipment, but these are so varied that they cannot be considered as standard equipment. Cutting tools which lose their cutting properties when dull must be taken care of by resharpening, and the tool crib should be provided with the necessary grinding machines for drills, reamers, cutters, and forged tools.

In addition to the above, there are certain other tools which may be considered more nearly a part of the actual shop equipment. These tools are in the nature of surface plates, straight-edges, parallels, V-blocks, C-clamps, vises, etc. Also, certain other instruments, such as surface gauges, micrometers of large size, calipers, special gauges such as gauges for taper sockets, thread gauges, and other instruments for determining standard shapes, tapers, and so forth, should be provided.

The toolmaker is ordinarily considered to have an equipment of tools of his own, such as small size micrometers, calipers, surface gauges, squares, and protractors; and although some of these tools may be included in the shop equipment, they are more in the nature of special instruments sued for checking purposes and for testing. Omitting tools of this kind from the discussion, then, we have as a part of the shop equipment the tools that are in daily use and kept in the tool crib strictly for the use of the workmen in producing work to the best advantage. We have also the tools which are fastened in place, such as vises which are bolted to benches all around the shop.

Surface Plates.—Referring to Figure 53, the upper illustration, A, shows a form of surface plate which should be considered as a part of the standard equipment of any factory. Plates of this kind are made of

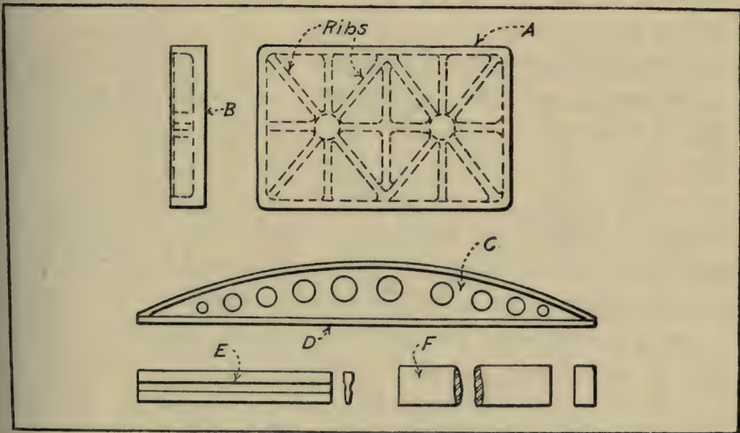


FIG. 53. SURFACE PLATES AND STRAIGHT EDGES

cast iron, well ribbed so that they will not easily get out of alignment. The surface of the plate, B, has been planed and scraped to a perfect plane, so that it can be used for testing other surfaces or for the fitting of parts. Several of these plates of different sizes can be found in any toolroom set up here and there on the workmen's benches. When a piece of work is to be tested or laid out with a scriber or surface gauge, surface plates are essential. Also in fitting another plate or piece of work which must be a perfect plane, the surface plate, rubbed with a little Prussian blue, can be brought in contact with it in such a way that the "high spots" will show a blue mark from the contact. These blue marks can then be scraped off with a hand scraper, as described in Chapter I. A plate of this kind is more often used in the toolroom than in any other department, although every department in the shop should have one or more for testing purposes, and for gauging and laying out work.

Straight-edges and Parallels.—It is often necessary to determine whether a surface is straight or not, and this determination is also a valuable adjunct in setting up. The ordinary straight-edge, C, Figure 53, is generally kept in the toolroom and taken out by a workman when he needs it. It is usually made of cast iron, with a face, D, which has been scraped to a perfect plane. In order to lighten the tool and make it more convenient for a workman to handle, a number of holes are pierced through it as indicated in the illustration. Straight-edges are made in lengths from 18 inches to 15 feet, according to the work for

which they are intended; special sizes can be obtained to order. These straight-edges are not commonly used for the smaller varieties of work nor for the very finest class of work.

Another type of straight-edge, E, Figure 53, usually called a toolmaker's knife-edge straight-edge, may occasionally be found in tool cribs, although it is more often a part of the toolmaker's personal tool kit. These straight-edges are used for work that requires extreme accuracy. Hence, they are made from the best quality of steel treated with the utmost care to insure that they will be straight and true. In the finest kind of toolmaking work these straight-edges are extremely valuable, and the workmen who use them take the greatest care to see that their accuracy is not impaired through springing or injured by being dropped.

Parallels, F, Figure 53, are found in great variety and in numerous sizes in the tool crib. They are useful for setting up work of more or less irregular shape when the work has been previously machined on one side and can not possibly be clamped to the table of the machine for a succeeding operation. Parallels may be made of steel or of cast iron, depending on their size; the smaller parallels are usually made of steel and the larger sizes of cast iron.

Frequently a piece of work may be set up and clamped to a pair of parallels and machined when it might otherwise be very difficult to hold the piece without a special fixture of some sort. In fact, the uses of parallels in any factory are so many and their application is so varied that it is difficult to mention

all of their uses. It may be said, however, that no factory can be called complete without having as a part of its shop equipment a great number of parallels of different sizes and sections.

Hand Vises.—One of the most important things in machining any piece of work is to hold it firmly. As the shapes which are to be held are of so many varieties, shapes, and sizes, it is obvious that there must be numerous types of holding devices which can be applied to the work. The importance, therefore, of the various clamps which are used for hold-

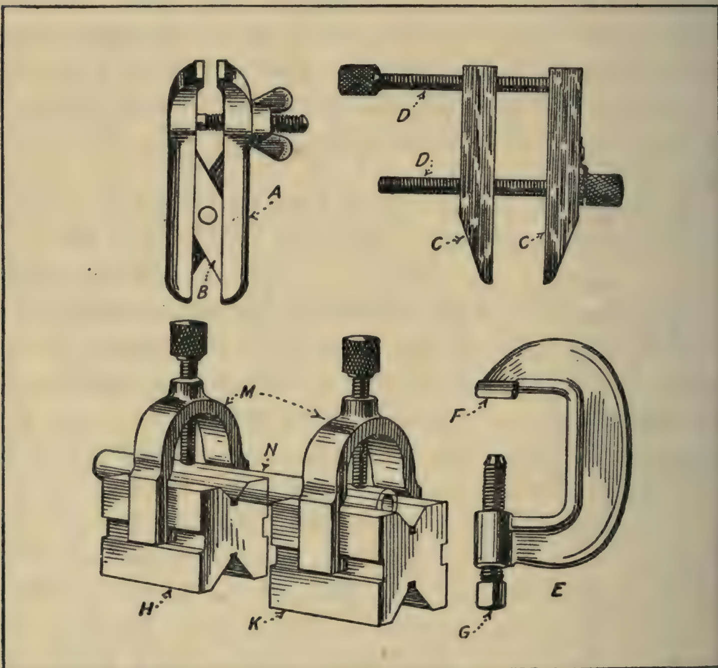


FIG. 54. HAND VISES, C-CLAMPS, AND V-BLOCKS

ing work, locating two pieces in definite relation to each other, and so on, in all kinds of operations, cannot be overestimated.

A group of small tools which can be considered as a part of the standard equipment of any factory is shown in Figure 54. The hand vise, A, may be used for a variety of purposes by the toolmaker or other workman. It will be seen that the jaws of the vise are kept in a state of parallelism by the equalizating cross, B. When the thumb-nut is operated, the jaws open or close according as the nut is loosened or tightened. For holding a small piece of work on which a filing operation is to be done, for example, a hand vise of this kind is very useful; and for numerous other operations which require the holding of a piece of small work in a certain fixed position this tool is almost indispensable. As a general thing this tool is more frequently found in a toolmaker's kit than in the tool crib.

It is often necessary to hold two pieces of work together when some machining operation is to be performed on them—for example, when two pieces are to be drilled and reamed together. In such work the toolmaker's clamp, C, Figure 54, is an important accessory to the tool crib. This clamp is really a type of hand vise in which the two jaws, C, C, are tapped to receive the thumb screws, D. The two jaws are operated by means of the thumb screws, and can be tightened by the fingers upon a piece of work. If additional pressure is needed, a pin hole in the end of the screw can be used as a holder for a small lever. Ordinarily this clamp is used for holding fin-

ished pieces together, not those which are in a rough state.

C-Clamps.—When rough work is to be held firmly, or when a piece of work is to be clamped down on a machine or clamped against a parallel, the C-clamp, shown at E, Figure 54, is generally used instead of the toolmaker's clamp previously mentioned. This C-clamp is provided with an anvil, F, and a screw, G, by means of which the necessary pressure can be exerted. The body of the clamp is usually a drop forging which is capable of withstanding considerable pressure. C-clamps should be found in the tool crib in great variety, both as to size and also in regard to the depth or throat opening which determines the sizes of work that may be held. For holding large work on the planer or milling machine and for a variety of other purposes in connection with manufacturing, the C-clamp is used to a great extent and must certainly be included in the shop equipment.

V-Blocks.—When a piece of round work is to be held so that it can be drilled or otherwise machined and no fixture has been designed for the work, one or more V-blocks, H and K, Figure 54, can be used to make up a temporary fixture. The particular type illustrated has a groove along the side to which a special form of clamp can be applied, as indicated at M. The arrangement shown in the illustration is used for holding a tube, N, to locate it properly for machining operations—drilling, milling, or cutting a key-slot. The bases of the V-blocks are parallel with a centerline of the V-shaped cut in the block, so that when the work is set up on the machine it will lie

parallel to the surface on which the blocks are clamped.

V-blocks are often used for straightening a piece of work. In this case the work is clamped by two of the blocks in such manner as to bring the bent portion between the blocks where it can be struck with a hammer or straightened under an arbor press. The application of the V-block principle to many forms of mechanical work will be further described in Chapters XVII and XVIII.

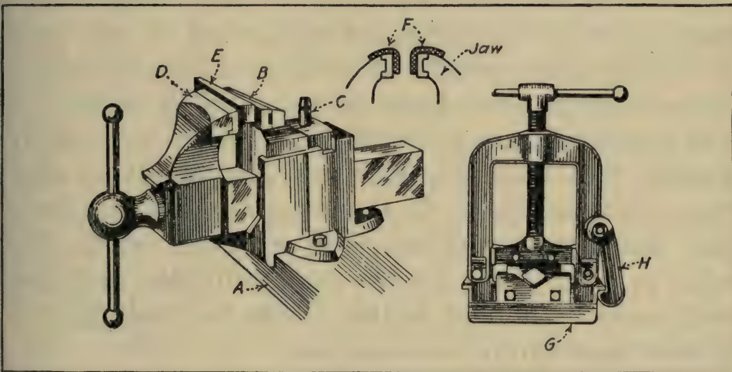


FIG. 55. BENCH AND PIPE VISES

Bench and Pipe Vises.—Any attempt to describe the shop equipment of the factory without mentioning the bench vise would be very much like a dinner without dessert or a roast of beef without salt. The bench vise, A, Figure 55, is an ordinary type of machinist's vise which is bolted to the workmen's bench at frequent intervals in every department. The type shown is equipped with a swivel jaw, B, by means of which a piece of tapered work can be firmly

held without slipping. A pin, C, is provided to locate this swivel jaw in a fixed position parallel to the movable jaw, D. A tapered piece of work, E, is shown clamped in position in the vise. It is evident that vises of this kind are an absolute necessity in any factory, no matter what the product or how large the factory. There are so many operations which need the assistance of a vise that it would be out of the question to attempt to describe all of its uses.

When a bench vise is to be used for holding a piece of finished work or something which must not be marred, it is often provided with a set of soft jaws, F, usually made of babbitt metal or copper, but sometimes made of sheet brass or tin. Babbitt metal jaws are very short lived and crush or break very easily, so that they become useless in a comparatively short time. Copper jaws or those made of heavy brass will last almost indefinitely if carefully used. The vises in many shops are provided with false soft jaws for general use, and babbit molds for making jaws of this kind are in common use.

The pipe vise, G, Figure 55, is frequently found in shop equipments, although its principal use is in plumbing work and pipe fitting. It is a convenient accessory for shop use, however, although one vise in a department is usually considered sufficient. The type shown is provided with a set of V-shaped corrugated jaws which grip cylindrical work and prevent it from turning while a thread is being cut. The upper jaw is operated by means of the screw and handle shown, and the latch, H, allows the entire upper part of the vise to be backed out of the way.

CHAPTER IX

MACHINE EQUIPMENT

Necessity for Proper Tools.—A man may purchase a machine at considerable expense and may find, after it has been in use for a while, that he is not getting as much out of it as he expected to. This may be for one of several reasons: It may be that the operator is inclined to loaf on the job; it may be that the cutting speeds and feeds are not correctly determined; or it may be that the tool equipment is inadequate. Disregarding for the time the first and second cause, it is certain that any machine to perform its functions in a satisfactory manner must have a proper equipment of tools.

When the work is of the interchangeable variety the matter of tool equipment needs most careful consideration. And even for the ordinary machine equipment certain tools are indispensable if the work is to be turned out in good style and with a minimum expenditure for labor. The equipment of the tool crib for standard machines in any factory, therefore, should be very complete, so that the workman will never be obliged to use a "make-shift" method in preparing to do any piece of work.

When boring out a drill jig for bushing holes, or something of this kind, the toolmaker, naturally, is

obliged to use a certain amount of ingenuity when he "sets up" work on the machine. However, this display of ingenuity should not be considered in the line of a make-shift, because in such work each job is a special one and needs special care in the setting up.

In this chapter I will consider only the type of tools which may be considered as a part of the standard equipment and those which should be kept in the tool crib as a part of such equipment. Tool equipment for various machines has been or will be taken up in this book, under their proper headings, but the types I will describe at this time, although they may be similar in some respects to the others, are decidedly ranked as standard equipment.

Drill Chucks and Sockets.—Referring to Figure 56, the drill socket, A, is tapered on the outside to fit the spindle of the drill press, and the tang, B, acts as a driver. A "taper shank" drill is used in a socket of this kind, the tang of the drill being driven into the slot, C. These sockets form a part of the equipment of any tool crib. They are made up in various standard sizes for different kinds of tapers. These tapers are slightly different for various machines, and are known as Morse taper, Brown & Sharpe, Jarno, etc. They are designated by number and name, and are all slightly different, both in sizes and also in the angle of the taper. For instance, if a drill press, having a No. 4 Morse taper hole in the spindle, is to use a comparatively small drill having a tapered shank of No. 2 Morse taper, a socket having a No. 4 taper outside and a No. 2 taper inside

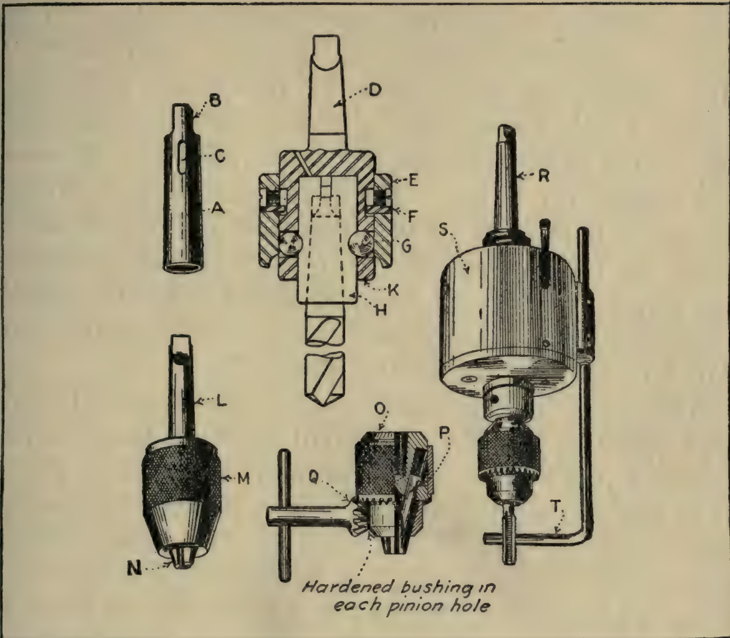


FIG. 56. DRILL CHUCKS, SOCKETS, AND TAPPING ATTACHMENTS

would be selected. The No. 4 taper would fit the spindle of the machine and the inside of the socket would fit the shank of the drill to meet the condition required.

An excellent socket for drill press use possessing many advantages is shown at D, Figure 56. This is known by the trade name, "magic chuck," and is made by the Modern Tool Co. When a number of sizes of drills or other tools are to be used in succession in manufacturing work, a socket of this kind is extremely valuable, for tools can be changed with

great facility while the machine is running. The socket proper has a tang that fits the spindle of the drill press. On the outside of the socket a sliding sleeve, E, fits loosely and is prevented from dropping off by the small retainer, F, which rests in a groove cut around the chuck. The lower part of the sliding sleeve is bored out to the diameter of the two steel balls, G, lying normally in opposite drilled holes in the chuck. A special form of adapter for the drill, shown at H, has a tapered hole and a slot in the end for driving the tang of the drill.

The action of the chuck when in use is as follows: The operator has the tool—drill or other tool—in its socket but not in the chuck proper. In order to place it in position while the spindle is revolving, he grasps the sleeve, E, and lifts it with his left hand. This allows the balls, G, freedom to run out into the annular groove, K, so that the socket, H, can be pushed up into the hole. When the socket is pushed in to its full depth, the sliding sleeve, E, is released, and the balls, G, are forced back thereby into their grooves on the outside of the socket where they act as drivers for the tool. If, for instance, several holes of different sizes are to be made on a one-spindle drill press and an equipment of Magic sockets is available, it is easily possible for an operator to substitute one tool for another and complete the hole in very short order without stopping the machine during the process of the work. Chucks of this kind are very useful as a part of the tool crib equipment.

When small drills of the straight shank variety are to be held, another type of chuck is generally used.

if they are of the smallest sizes, not requiring any great pressure to drive them, the type of chuck, L, is commonly employed. This chuck consists of a sleeve, M, threaded to the outside of the body of the tool and having an inside tapered portion which draws in on the three jaws, N. The jaws, in turn, grip the drill and center it at the same time. A chuck of this type is very common and should be found in every tool crib.

Another type of chuck for drills which are a little heavier but have straight shanks is shown at O, Figure 56. This chuck is made by the T. R. Almond Mfg. Co. The upper end fits a shank which is tapered to go into the drill press spindle. The three jaws, P, are controlled and moved in or out by the action of a bevel gear and threaded nut which is operated by a special wrench having a bevel pinion, Q, at the end. This chuck also is a very useful adjunct to the tool crib.

Tapping Attachment for Drill Press.—When it is necessary to tap a hole or series of holes in a piece of work, and it is desired to perform the operation by means of a machine instead of by hand, a tapping attachment may be used for the work, applied to a drill press of the ordinary variety. The attachment, R, Figure 56, is made by the Braden Mfg. Co. This mechanism is so arranged that the spindle of the machine, when raised after the bottom of the hole has been reached, automatically reverses the direction of rotattion of the tap so that it backs out of the hole.

The operation of the mechanism is as follows: The

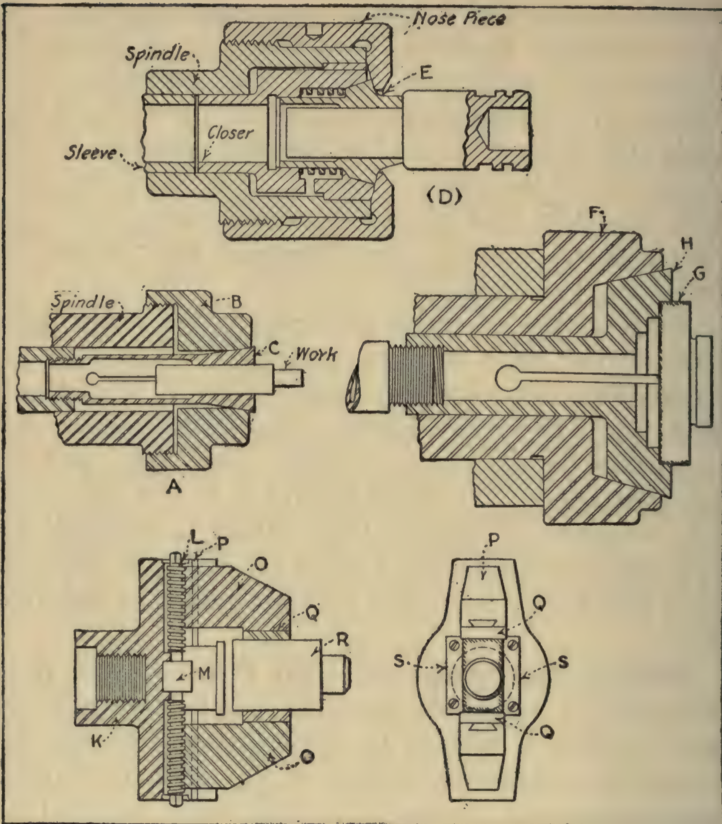


FIG. 57. COLLETS AND CHUCKS

spindle is raised and lowered with the right hand while the work is inserted with the left hand, so that the operation of the mechanism is almost continuous. The reversing gears are enclosed in a dustproof case, S, and need practically no attention. The gauging of the depth of the hole can be taken care of by

means of the adjustable stop, T. Several mechanisms of this kind are on the market, each of which has some feature to prevent the breaking of taps and also to make it unnecessary to reverse the spindle of the machine when in operation.

Collets and Chucks.—Collets, sometimes known as draw-in chucks, are used on many types of machines. Probably the use to which they are most often applied is in the holding of bar stock on the screw machine. They are also employed to a considerable extent on toolmakers' lathes, bench lathes, jewelers' lathes, screw shavers, and the like. As a part of the shop equipment, however, their application is generally to the toolmakers' lathes and the screw machine.

Several types of collets are used for these machines, but for stock of small size the mechanism is most frequently like that shown at A, Figure 57. In this case the spindle is fitted with a nose piece, B, having a tapered hole in the forward end. A spring sleeve, C, is split in several places around the periphery in such a way that it will draw in or contract as it is pulled back into the tapered end of the nose piece. The method of pulling the collet back differs with the machine to which it is applied. In the case of a bench lathe or toolmaker's lathe the mechanism is usually operated from the end of the spindle by means of a handwheel. When the device is applied to a hand screw machine, the draw-in mechanism is usually operated by means of a handle at the rear end of the spindle, but the action of the collet jaws in gripping the work is identical to that shown in the illustration.

Several other types of collets are made for work of larger size, but these are more in the nature of chucks, and the jaws of the collet are loosely held and have no forward or backward movement. An example of a collet chuck of this kind is shown at D, Figure 57. In this case the nose piece is screwed to the end of the spindle and the jaws, E, are operated by a closer which slides forward on the tapered portion of the jaws when the sleeve indicated is pushed forward through the spindle. A particular advantage of this type of chuck is that there is no longitudinal movement to the jaws as they contract and expand. They can be used, therefore, for second operation work (that is, work which has previously been partially machined) with the assurance that the longitudinal position will come the same in every case.

Step Chucks.—After a piece of cylindrical work has been machined in a previous operation and other work is to be done on it which will be true with that previously done, it is frequently held by the previously finished surface in either a collet, such as that noted in the preceding illustration, or by means of a step chuck such as that shown at F. Or an expanding arbor may be used when the work previously done has consisted of boring and reaming a central hole in the piece. The step chuck principle, as shown at F, is extremely useful for finishing work of this character, G. The step chuck body, H, is operated by means of a mechanism in the same manner as the collet jaws previously mentioned. The chuck itself, however, in this case is made of soft material, so that it can be machined to the proper

size to hold the work while it is in the machine on which it is to be used.

Taking the case shown as an example, the method of "stepping out" the chuck would be to place a piece of round stock of small diameter in the jaws and set up the closing mechanism. This work would be done on the machine. While in this condition, the chuck would be bored out to the diameter required for holding the blank, G, after which the cylindrical piece would be taken out of the chuck which would then be ready for use. It will be seen that this mechanism is exactly similar in action to the collet shown at B, except that it is of larger diameter and, consequently, has a greater latitude.

Two-Jawed Chucks.—Two-jawed chucks form a very useful part of the machine equipment, particularly on small hand screw machines in the holding of irregular work or pieces which cannot easily be held in a three-jawed scroll chuck. A chuck of this kind is shown at K, Figure 57, the small end being screwed directly to the end of the spindle. This chuck is commonly operated by means of a wrench, although various applications are made which provide a means of operating that is quicker than the wrench method. Sometimes compressed air operating on a plunger through the spindle is used, and at other times a wedge or a rack-and-pinion is used, depending on the type of chuck and the method advocated by the manufacturer.

In the type shown, the mechanism is controlled by means of a right- and left-hand screw, L, which is journaled at M in the body of the chuck in such

manner that it has no crosswise movement. The jaws, O, are tongued to fit a slot, P, running across the chuck, and the lower portion of the jaw is tapped out to receive the body of the right- and left-hand screw, L, previously mentioned. It will be seen that as the screw is operated, the jaws move in or out, according as the screw is turned to the right or left.

Jaws of this kind are frequently provided with a dovetail into which sub-jaws, Q, can be inserted. This is done so that the same chuck can be used for a number of different pieces by simply making up a set of sub-jaws or inserted jaws of the desired form. In the instance shown in Figure 57, the work, R, which is being held, is of rectangular form, and the chuck is provided with two locating plates, S, to give the sidewise location while the jaws center the work in the opposite direction.

When a two-jawed chuck is to be used for holding an irregular piece of work, the inserted jaws are generally formed to the desired shape, after which they are hardened and set in place in the chuck. Jaws of this kind are very useful for small, irregular-shaped forgings or castings, and also, when applied to the larger variety of chucks, they can be used for heavier work of irregular form. For example, a lever having a long hub and a crooked arm, could be nicely held in a two-jawed chuck, with jaws shaped to fit the hub and so arranged that the lever arm would act as a driver. Such jaws may also be formed out to a radius to fit thin brass or bronze bushings which are to be bored and reamed; when formed in this way the bushings can be held so that

there is very little distortion caused by excessive pressure in holding.

Geared Scroll Chuck.—The ordinary chuck used for centering work on either a lathe or turret lathe is a three-jawed geared scroll chuck of a variety similar to that shown at A, Figure 58. Chucks of this kind have an excellent centering action, as the jaws are spaced at 120 degrees apart and all are moved radially toward the center with an equal movement. This type of chuck can be mounted on a faceplate, as indicated at B, which is screwed to the end of the spindle of the machine, or the chuck can be so designed that it screws directly onto the end of the spindle. In either case the internal mechanism is the same, and is practically like that shown in the illustration. An annular ring, called the scroll, lies in a recess as shown at C. This recess runs entirely around the chuck and the scroll portion engages with the bottom of the three jaws, D, which are also tongued on their sides into radial slots in the body of the chuck. The face of the jaws is tongued to receive special jaws of different form, like that shown at E in the figure. These jaws are fastened by the two screws shown and can be replaced by others at any time with very litle trouble on the part of the operator.

The chuck is provided with three pinions of the bevel type, F, which mesh with a bevel gear cut on the back of the scroll ring. When any one of these pinions is turned, by means of a socket wrench provided with the chuck, the scroll, C, revolves in its bed and carries the chuck jaws radially inward or

outward, according as the pinion is operated to the right or left.

Air-Operated Chucks.—The advantages of compressed air and the many uses to which it can be applied in the factory are becoming more and more appreciated by the progressive manufacturer. Some years ago considerable interest was shown when a machine-tool builder of international reputation designed and built a very large fixture for use in his own plant, which had a series of clamps by means of which the work was held, the clamps being operated by compressed air. An additional refinement was supplied by the designer in the introduction of a pressure valve so arranged that the amount of pressure applied to the clamp could be adjusted to provide the same amount of pressure under any condition. As the work was of large size and peculiar shape, there was danger of distortion if Tom, Dick or Harry were permitted to exercise his judgment in regard to clamping the work, but the application of compressed air and the pressure valve made the matter of holding an absolutely safe proposition.

In the past few years methods of chucking or holding work on the turret lathe or screw machine have received a great amount of attention, and the principle of holding by means of compressed air has been made use of by several manufacturers. A very successful type of air chuck, made in a number of varieties by the Hannifton Mfg. Co., is shown at G, Figure 58. In the type shown the jaws are three in number, as shown at H, and on these jaws an adjustable jaw, K, is mounted. By means of the screw, L,

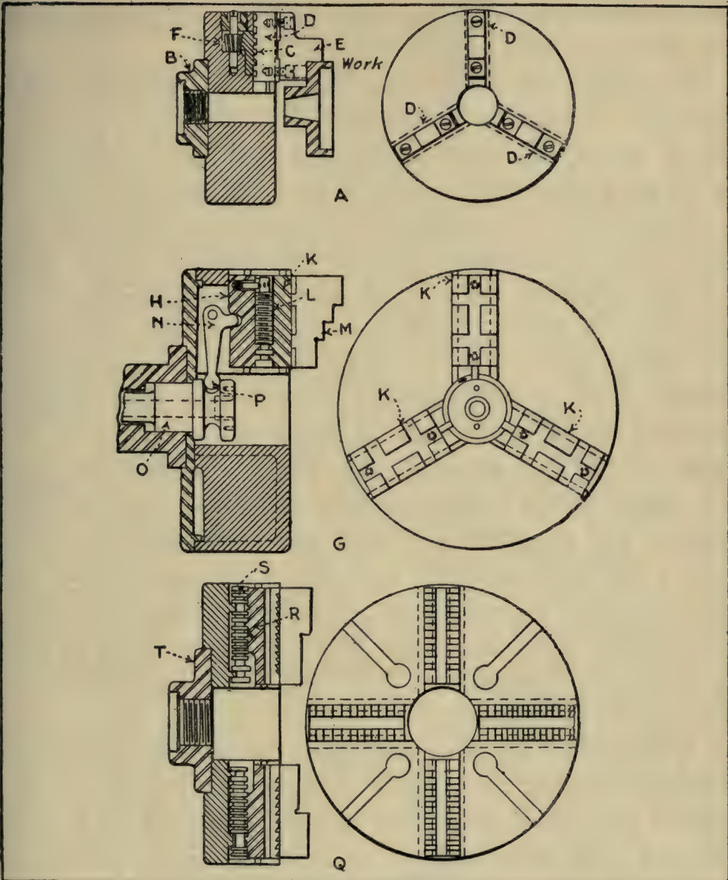


FIG. 58. THREE VARIETIES OF CHUCKS

these adjustable jaws, K, can be set in or out in a radial direction toward the center of the chuck to provide for holding pieces of different diameter, or they can be set eccentrically at different distances from the center to suit any particular case. On the

adjustable jaws the work-holding jaw, M, is located by means of the tongue shown.

The operation of the mechanism is as follows: The chuck is slotted in three places to receive the operating levers, N, each of these levers being provided with an arm which enters a slot on the rear side of the jaws, H. A plunger, O, runs back through the spindle and connects with the air cylinder at the rear of the spindle. The front end of the plunger is so grooved that it engages with the three lever arms as indicated at P. When it is desired to operate the chuck jaws, a conveniently located two-way valve is opened, allowing the air to enter the cylinder at the rear of the spindle and pull back upon the plunger, O, which in its turn, operates the lever arm, N, that moves the jaws inward in a radial direction to grip the work firmly. The amount of pressure used can be regulated by means of a pressure valve if desired, depending upon the work which is to be held, so that a delicate pressure or a powerful clamping action can be readily obtained.

Air chucks of this kind are extremely useful for chucking work of various kinds on turret lathes and screw machines, and they can be obtained in a number of sizes and shapes to suit the most fastidious customer. It is evident that special jaws can be adapted without difficulty to chucks of this kind, so that they can be made to handle a variety of work.

Four-Jawed Independent Chuck.—In the course of general manufacturing, or for work in the tool-room, it happens occasionally that a piece of irregular shape needs to be held. In a case of this kind the

three-jaw chuck cannot be used to advantage since it is adapted only for work which can be centered. For tool-room work an independent chuck is frequently used for holding irregular shapes, the workman setting up the piece in the jaws approximately to the center which is to be bored or drilled and then using an indicator on the work to indicate the exact center. Such a chuck is shown at Q in Figure 58. It will be seen that this chuck is indispensable both in the tool-room and for general manufacturing for holding irregularly-shaped pieces on the turret lathe or on the boring mill. When a number of pieces of the same kind are to be chucked one after the other, and when these pieces cannot be held by the ordinary three-jawed, geared, scroll chuck, it is customary to set two of the jaws, or more if possible, to the proper center to act as a vee in locating the teeth. The work is then placed in the chuck with the proper surfaces against the two fixed jaws, and the other jaws are brought up independently. The construction of this chuck is clearly indicated in Figure 58. The jaws are moved radially by the screws, S, which in their turn are controlled by a socket wrench (not shown in the illustration). The body of the chuck is generally fastened to a faceplate, as shown at T, which is screwed to the nose of the spindle. The face of the jaw is provided with a series of notches, so that a special jaw of any particular kind can be easily attached to it. As ordinarily furnished, the chuck is supplied with one or more sets of jaws stepped out at different diameters, so that a variety of work can be held without recourse to special jaws.

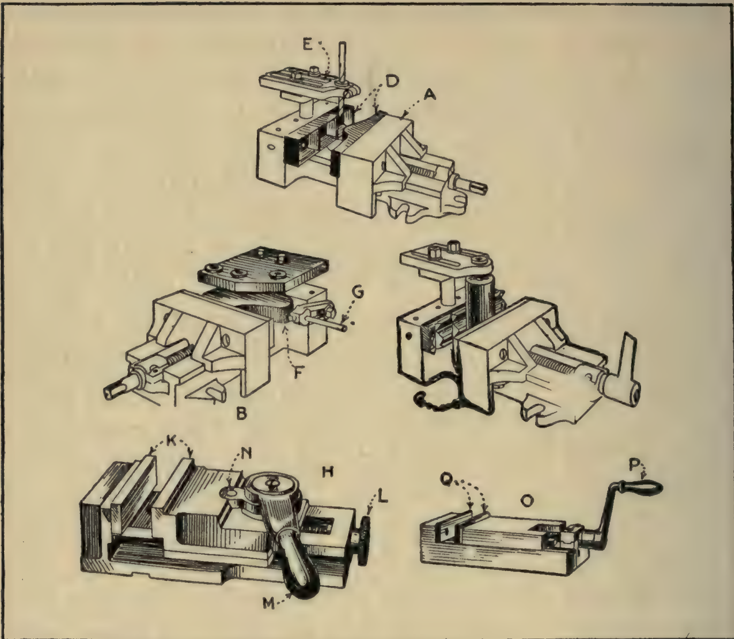


FIG. 59. MANUFACTURING AND MACHINE VISES

Machine and Manufacturing Vises.—The importance of the proper way of holding a piece of work to be machined cannot be overestimated. Hence, vises are used on many classes of machines for holding work during the process of machining. They are particularly useful on the milling machine and the drill press; and recent developments along these lines have developed a particular type of vise called a manufacturer's vise. This vise is more or less adaptable, and suitable stops can be applied and locating pins put in for the purpose of locating a

small number of pieces and holding them securely. Attachments provide for drill bushings of different sizes, and drill plates to hold the bushings can be applied with little trouble. The Graham Manufacturing Co. makes a useful tool of this kind, as shown at A, B, and C, Figure 59. The upper figure, A, shows the vise supplied with special jaws, D, and a drill plate of an adjustable type, E, which can be moved to any desired location over a piece of work held in the vise jaws. The figure, B, shows another plate applied to the same type of vise; the work, F, is held between the vise jaws and obtains its endwise location against the stop, G, which is likewise adjustable. A third application of this vise is shown at C, where a set of special jaws of V-type are used to center a piece of round work, and the drill plate is set centrally so that the vise can be used as a centering jig.

An excellent type of machine vise employing a cam as the locking principle is shown at H, Figure 59. This vise, made by the F. C. Sanford Manufacturing Co., is an excellent example. It can be used as an ordinary vise and adapted to special conditions with standard jaws, as shown at K, or these jaws can be made up in special form to suit particular cases. Approximate location of the jaws is obtained by means of the screw, L; after the location has been obtained the entire locking movement is made by the lever, M, which is eccentrically placed with relation to the link, N, by means of which the jaw is locked. Manufacturing vises of this type are coming more and more into use and several varieties are on the

American market. They are made in a number of styles and sizes to suit different conditions.

The ordinary machine vise commonly found on the milling machine, also useful in drill press work, is shown at O, Figure 59. This type of vise is operated by a sliding jaw, controlled by a screw which, in turn, is manipulated by the handle, P. This vise is made by the Brown & Sharpe Mfg. Co., and can be provided with false jaws to hold special forms of work, as indicated at Q. A vise of this sort is found in every tool crib, usually in several sizes.

Taps, Dies, and Holders.—The ordinary method of cutting a thread on the outside of a single piece of cylindrical work is to "chase" it on an engine lathe with a single-point tool, gearing up the lathe to the proper pitch, or number of threads per inch, and taking several cuts successively upon it until the desired depth has been reached. When a hole of odd size is to be threaded in a piece of work, the same method may be employed, but the type of tool used is one adapted to internal cutting. Both procedures may be used with success, but they are uneconomical unless the work is of particular accuracy and difficult to get at with some other types of threading tools. A properly equipped tool crib should be provided with complete sets of taps, dies, chasers, and suitable holders for them, so that any type of standard thread can be cut without difficulty. If the thread to be cut is difficult of access, the lathe method may be the only one possible.

Figure 60 shows, at A, a standard type of hand tap which is commonly used in connection with a

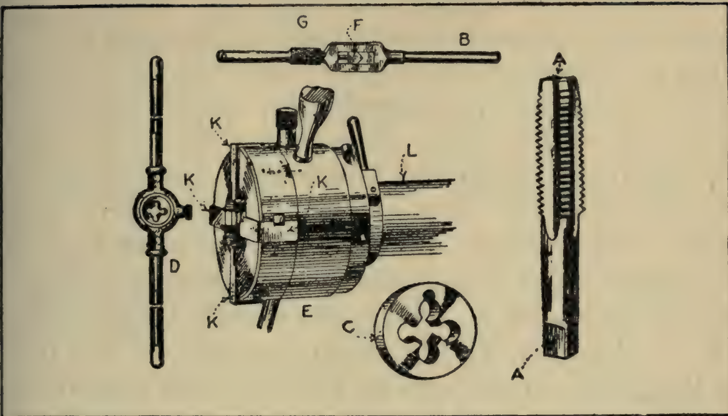


FIG. 60. TAPS, DIES, AND HOLDERS

wrench, B, for tapping out a hole by "man power." The tap itself is squared on one end so that it can be readily held in the adjustable jaw, F, by a turn of the threaded handle, G. The same taps are also used in a releasing tap holder when used on a turret lathe or a hand screw machine. The ordinary type of spring threading die, shown at C, in the same illustration, is commonly used in a die holder such as that indicated at D. Such a die is used for threading screws, studs, or other cylindrical work, either by hand or by a screw machine; the holder, D, being used when the work is done by hand. A special type of holder is used on the screw machine, which is of the releasing variety such as that used for holding a tap on the same machine.

If the taps and dies mentioned are used on a screw machine or turret lathe, it is necessary to reverse the machine in order to back off the tap from the

work after the thread has been cut. So also, the spindle on the engine lathe must be reversed in cutting a thread and the tool run back out of the way. (The more modern varieties of engine lathes are provided with a form of indicator which makes a reversal of the spindle unnecessary.) Naturally a considerable loss of time is entailed by this operation, and in order to overcome it another type of die head, called an opening die, can be used, whereby it is unnecessary to reverse the spindle. An opening die of this sort, E, Figure 60, is made by the Geometric Tool Co. It can be supplied with chasers, K, which may be made for any form or pitch of thread within the capacity of the die head. The chasers accurately fit slots cut to receive them in the face of the die head, as indicated in the illustration.

In operation, when used on a turret lathe or hand screw machine, the shank, L, is held in the turret and the open end, containing the chasers, is fed onto the work until a predetermined stop has been reached, at which time the chasers fly open and permit the die head to be drawn back out of the way. These die heads are extremely useful in manufacturing work. Although their first cost is high, the fact that a single size of holder can be used for many sizes and varieties of threads by the simple substitution of a different set of chasers, makes it an economical proposition in the machine equipment.

CHAPTER X

FIXTURES FOR PLAIN AND STRADDLE MILLING

Nature and Variety of Fixtures.—The process of milling has taken the place of planing to a great extent in the general processes of interchangeable work, except in cases where the size of the piece is too large to be handled to advantage on a milling machine, or when the accuracy required, or the shape of the piece is such as to make it impossible to mill the surface. There are a number of different types of machines which are adapted to the milling process and it naturally follows that the type of milling fixtures which are used on the various machines must be so designed that they will apply to the particular type on which the work is to be done. Thus, if a piece of work is to be handled on a milling machine having a horizontal spindle, the fixture will be so designed as to present the work to the cutter revolving in the same way that a carriage wheel turns. Or again, if a fixture is to be used on a milling machine having a vertical spindle, the fixture must be so designed as to present the work to the cutter revolving in a horizontal plane, like a top.

The two most important types of milling machines used in manufacturing are those having a horizontal

spindle and those with a vertical spindle. Variations of these types are found in those that have more than one spindle, such as duplex machines and multiple-spindle machines. In the duplex type, the spindles are opposed and can be adjusted towards each other until the ends of the cutters strike. The multiple-spindle machines have from four to seven spindles, some of which are arranged horizontally and others vertically.

It is evident that in the design of any milling fixture, the first point to be taken into consideration is the nature of the work and the material to be cut. The next point is the type of machine which is best adapted to the work; and the third point is the method of holding the piece when it is being machined.

Necessity for Proper Holding.—The most important point in connection with the design of milling fixtures is the proper holding of the work; for it must not be distorted by the pressure of the clamp used in holding it in place and, at the same time, the method of clamping must be so rigid that there will be no possibility of "chatter" which would result if the work were allowed to swing out of position under pressure of the cut. In this matter of holding, the ingenuity of the tool designer is the important factor, also, the lift or dragging action of the cutter while it is engaged with the work must be considered.

A piece that has previously been partially machined, with either holes, slots, or other finished surfaces, will naturally require different holding methods than those used for rough castings or forgings. For in performing a second or third operation on a piece

of work, it is essential that the location should be positively determined by one of the finished surfaces. Which surface is to be used as a locating point must be determined by the nature of the work and the sequence of the various operations upon it. Let us assume, for instance, that a lever having a boss at each end has been drilled and reamed at one end through the boss, and that the other end is to be "straddle-milled." It is obvious, then, that in order to locate the piece properly so that the second milled surface on the boss will be at right angles to the hole, the work must be located by a stud in the hole, and must be set up on the fixture in such a way that the clamps will not spring it out of alignment.

In work that has not been previously machined and is still in the rough state, the locating points must be so placed as to center the work in relation to the cut which is to be taken for the greatest degree of profit.

Milling Fixture for a Connecting Rod.—An excellent example of a milling fixture designed to handle a drop forging of an automobile connecting-rod is shown in Figure 61, the work being shown at A, and the surface which is to be milled being the small end-boss, B. In this milling operation, which is called straddle milling, two cutters of the side-milling type, C, are set up on an arbor, D, and are properly spaced with a collar between them so as to make the distance between the cutting edges of the two cutters the same width as the thickness of the boss to be milled. In the example shown, the boss, B, is located in a V-block, E, the angular surfaces of which tend to

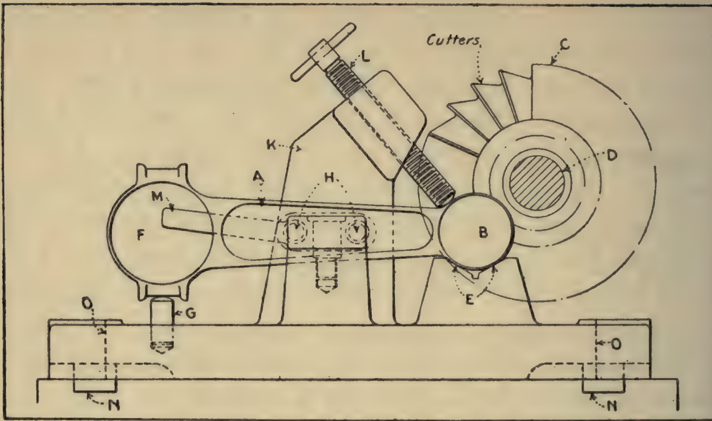


FIG. 61. SIMPLE STRADDLE-MILLING FIXTURE FOR A CONNECTING ROD

center the boss correctly. The large end, F, is dropped down upon a locating pin, G, in the base of the fixture, and two side stops in the form of pins, H, are set into the lug, K, which is a part of the fixture base. The upper portion of this lug is provided with a set-screw, L, which acts upon the small boss, B, to hold it firmly down in the V-block. A cam lever, M, works against the side of the connecting rod and throws the piece over against the two pins, H, which give the work its location.

A fixture of this kind may be manipulated very rapidly; the design is extremely simple and can be made cheaply. In addition to this, the method of holding the work and supporting it under the cut is so rigid that there is no likelihood of chatter. Such a fixture can be made up to hold a couple of pieces if desired, in which case two gangs of milling cutters

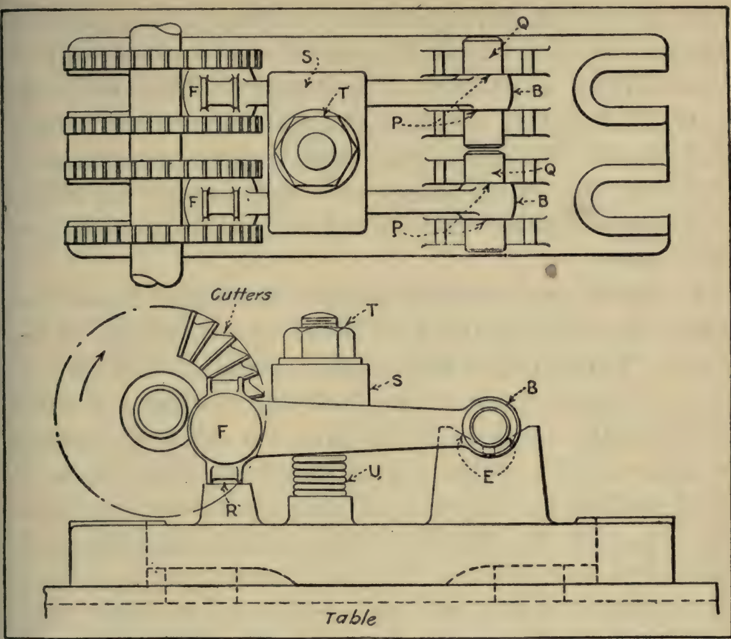


FIG. 62. DOUBLE-STRADDLE MILLING FIXTURE FOR AN AUTOMOBILE CONNECTING ROD

would be required. All milling fixtures are provided with keys such as those shown at N, and are also slotted, as at O, so that they can be held down on the table of the milling machine by means of T-bolts.

Straddle Milling Fixture Working from a Finished Surface.—The connecting-rod shown in Figure 61 is an excellent example of another type of fixture. Let us assume that after the first operation has been done, a hole is drilled and broached to size in the boss, B. After this operation it becomes necessary to mill the other end of the connecting-rod, using the

hole in the smaller boss as a locating point. In this manner the large boss, F, can be milled accurately at right angles to the hole. Referring to Figure 62, the method of setting up for this operation will be clearly understood. The plan view above shows two connecting rods, the small bosses of which have been milled with holes drilled and broached in the manner just described.

In the first place, the bosses, B, in the small end have plugs, Q, inserted in them which snugly fit the holes. These plugs rest in two pairs of V-blocks, E, for purposes of alignment, and the V-blocks are finished on the surfaces, P, so that the sidewise location is assured. The other end of the work which is to be machined drops down upon the finished pad, R, on the base of the fixture. When the connecting-rods are to be clamped in place on the fixture, the strap, S, is placed across the two rods and the nut, T, is tightened, thus securing the work firmly. A coil spring, U, is placed under the clamp in order to assist in raising it when the work is being removed from the fixture.

It will be seen that this method of locating from a finished hole, and also the method of clamping with a strap across both pieces, makes it possible to set up the work without any fear of distorting it or throwing it out of alignment. Fixtures of this kind are in common use on many varieties of work and can be applied to other instances in which the same principle is involved. Both of the fixtures shown in Figures 61 and 62 are adapted for use on a horizontal type of milling machine.

Gang Milling.—In milling several surfaces of varying depths on any piece of work, if the production is sufficient to warrant the work being done in a single operation with a gang of special cutters, a fixture should be designated so that the cutters may be mounted on an arbor to obtain the proper spacings and depths. A good example is shown at A, Figure 63.

In this case the work has several shoulders and several plane surfaces of different heights, as shown in the illustration. The milling fixture is of extremely simple type, and is nothing more nor less than a cast-iron block, B, grooved and finished at C and D to give the proper location to the work in relation to the table. A set-screw, E, or several set-screws, according to the length of the work, is used to clamp it against the surface, D. An important feature in the design of any sort of milling fixture in which the work is located against finished surfaces, is the groove, F, the purpose of which is to allow any dirt or chips which might accumulate in the fixture to be swept out of the way and passed down into the groove so that they will not interfere with the location of the work. The cutter gang, shown at G, H, I, J, and K, is so arranged that it will give the proper spacing and depth. Many varieties of work can be handled with a set of cutters of similar character to these, and the work can be produced at a rapid rate and within good commercial limits of accuracy.

End Milling a Slotted Bracket.—It is frequently necessary in the process of manufacturing to cut a

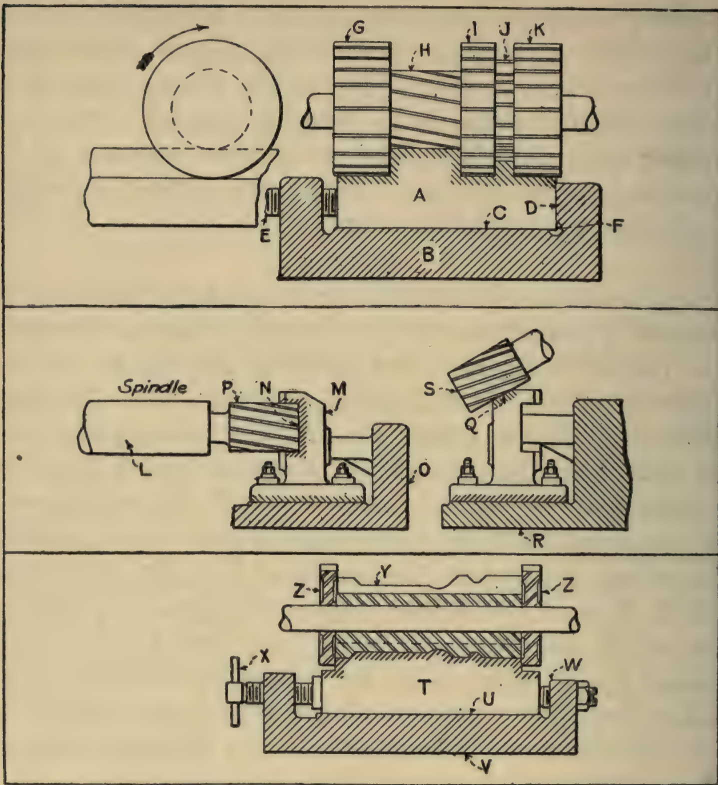


FIG. 63. FIXTURES FOR VARIOUS KINDS OF MILLING OPERATIONS

slot in a casting or forging which will bear a certain relation to some other finished surface. An example is shown in Figure 63 at L. In this example the bracket, M, has been previously machined at the side and base, and it is now necessary to cut the slot, N, in a certain relation to these two surfaces. The method of setting up the work in this case is very

simple, as the fixture itself consists of an angular plate, O, which is fastened down to the milling machine table in the usual manner. The work is located on the finished pad at the base and against the side surface, being clamped in position by means of the two bolts shown. The cutter which is used for this work is a spiral end mill, P, which is clearly shown in the fixture. In operation, the table feed of the milling machine is started and the work is run directly by the cutter at the position indicated.

Fixture for Angular Milling.—Taking as an example the same bracket shown at L, let us assume that an angular surface, Q, is to be milled upon it in another operation, bearing a certain relation to the previously finished surfaces. A piece of work of this kind may be handled in three different ways, but in order to make the application of the milling machine more clearly apparent, let us assume that in this case a horizontal type of machine is used which has a vertical milling attachment that can be swung to any desired angle. The procedure then would be to set over the vertical attachment to the desired angle of the finished surface, Q, and to locate the work horizontally as in the preceding instance, using a type of fixture shown at R, with suitable locaters and clamps. A milling cutter of the spiral end-mill type is inserted in the milling attachment as indicated at S, and the machine table is fed under the work while in the position indicated.

Another method of handling the same piece of work would be to build the fixture itself on an angle with the table, so that the surface, Q, which is being milled,

would lie parallel to the table itself. In such a case, an ordinary type of plain milling cutter would be used, the cutter having straight cutting edges parallel to the surface of the table. The work could also be performed in the same fixture as that shown by swinging the vertical milling attachment to another angle and using the end of the mill for making the cut, instead of the side of the mill as indicated in the drawing.

Fixture for Form Milling.—Let it be assumed that a piece of work, T, is to be formed to the contour shown. The work has been previously machined along the base, U, but has not been surfaced on the edges. It is necessary to reduce the form that is parallel to the lower surface and approximately in line with the edges of the work.

In this case the fixture, V, is of U-section, bolted to the table in the usual manner, and located by means of tongues in the table T-slots. Two adjustable studs, W, are furnished along the side, and against these studs the rough side of the work is located, being clamped firmly against it by means of the thumb-screws, X. It is customary, in work of this kind, either to build a fixture which will take a number of pieces of the same kind, or else to make the work in a single strip and cut it up into pieces of the desired length after it has been machined. Naturally, the process which is to be used determines the method of holding and clamping. The formed milling cutters, Y, and side milling cutters, Z, are made up to suit the contour of the work to be manufactured.

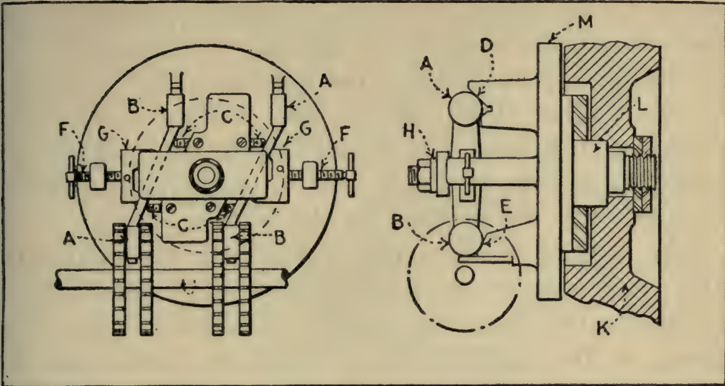


FIG. 64. DOUBLE INDEXING FIXTURE FOR STRADDLE MILLING LEVERS

Index Milling a Pair of Levers.—When rapid production is desired on a piece of work it may be possible and profitable to arrange a fixture similar to that shown in Figure 64. Here we have two levers of identical size, but the bosses on the ends are of two different widths. They can be machined in a single setting by a suitable arrangement of the fixture and cutter. In the case shown the levers have a boss at one end, as at A, and at the other end, as at B. The fixture is built so that it will hold the two levers in such a way that a large and a small end are successively presented to the cutters at A and B, and these cutters are spaced so as to mill different widths according to the thickness of the bosses.

The fixture locates the work in each case against the small set-screws, C, to give sidewise location against the sides of the lever, and suitable V-blocks, D, hold the bosses centrally. The V-blocks are at one

end only, the other ends rest against the angular surface, E. Thumb-screws, F, are provided on each side of the fixture to hold the work against the set-screw, C. A rocking clamp, G, on each of these set-screws equalizes any variation in the forging and makes the clamping action positive. An ordinary strap clamp, H, holds the work down on the fixture.

The method of using the fixture is to mount it suitably on a base, such as that shown at K, centering it by means of a central plug, L. The base is fastened down to the table of the milling machine, but the upper portion, M, can be swung around through an arc of 180 degrees so as to present the opposite ends of the levers to the cutters in sequence. Indexing is usually performed manually by the operator with some type of locating pin which gives the correct location when indexing from one position to another. A scheme for accurately indexing a piece of this kind will be described under the next heading. The foregoing fixture mills two ends of two bosses at the same time and is then indexed to mill the two opposite ends, so that four ends of the two levers have been machined at a single setting. But it must be recalled that a fixture of this kind is not economical unless a number of pieces are to be machined.

Index Milling Fixture for Quantity Production.—In work that is being put through a shop on the interchangeable system, as in automobile production or other manufacturing where a number of pieces of the same sort are to be successively machined to a given size, a number of pieces are usually found which require some sort of an indexing fixture for milling

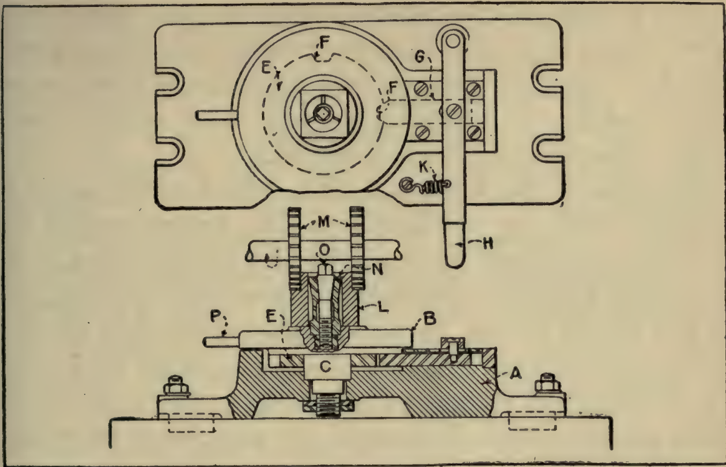


FIG. 65. SIMPLE INDEX-MILLING FIXTURE

slots, clutch teeth, and the like. The progressive designer of tools, therefore, usually designs some sort of universal milling fixture which has sufficient flexibility that it can be adapted to such a variety of work.

For example, while supervising the work on a large automobile plant equipment for a Russian corporation, I used recently the type of fixture shown in Figure 65 over twenty times on as many different cases. The indexing mechanism and the base of the fixture were practically the same in every case; the only differences were in the number of points of indexing and in the adapters which were used to hold the different shapes to be milled. A particular advantage in this type of fixture is its adaptability to different conditions, and also to the fact that it is practically impossible to destroy the correct indexing

of the fixture, as the mechanism is so well protected from chips and dirt that no trouble can be caused thereby. As this fixture is so notably flexible, it is worth while to describe it in greater detail than might otherwise be deemel necessary.

The base of the fixture, A, is fastened to the milling machine table by the bolts shown, being located in the usual manner by keys in the table T-slot. A revolving table, B, is suitably mounted on a stud, C, in the center of the base. On the under side of the table a hardened tool-steel indexing ring, E, is securely fastened by means of screws, and is provided with angular slots, F, around its periphery, as many in number as the indexing points which are to be made. A sliding block, G, is located radially in relation to the index plate and is tapered on the end which fits the angular slot in the index plate, thus determining the radial indexing points on the fixture. The movement of this sliding block is controlled by a handle, H, and it is drawn back into position by the spring, K, when the proper indexing point has been reached. It will be seen that the location of the slots in the index plate is such that it is practically impossible for any chips or dirt to interfere with the proper location of the table. The upper part of the fixture can be fitted with adapters of different kinds to hold various shapes or forms which are to be milled.

The work shown in the illustration is a cylindrical piece, L, which is squared up at the upper end by the two milling cutters, M. This piece of work is located on a spring stud, N, expanded by means of the bolt,

O, so that all chance of vibration is taken up and there is no possibility of chatter during the progress of the work. A hand lever, P, is provided on the table to index it from one position to the other; but this feature is unnecessary in many cases as the workman can use the work as a lever for indexing the table. However, a series of holes around the periphery of the table allow the pin to be inserted at different points to provide for a circular indexing movement when needed. This type of fixture is probably one of the most useful that can be made to handle a great variety of work, and although its first cost is fairly high it should not by any means be considered an expensive fixture.

CHAPTER XI

FIXTURES FOR CONTINUOUS MILLING

The Value of Simplicity.—It is an economical proposition, when a great number of pieces of the same kind are to be machined by the process of milling, to make the fixtures wherever possible in such a way that there will be as little lost time as possible caused by taking out and putting in the work. It is most advantageous to arrange a milling fixture in such a way that the cutters will be working as nearly continuously as possible. Several methods can be employed, depending upon the class of work to be done and the machine which is used for the work. On the regular type of horizontal milling machine some classes of work can be handled in an almost continuous manner; although the cutting action will not be absolutely continuous, there is very little lost time between cuts and it is unnecessary to stop the machine at any time.

A special type of milling machine, called a continuous miller, is made by the Becker Milling Machine Company. This machine uses a revolving table and a series of fixtures arranged radially on the table. The Potter and Johnston Company also make a continuous milling machine having an indexing table on which the work can be set up on one side of the table

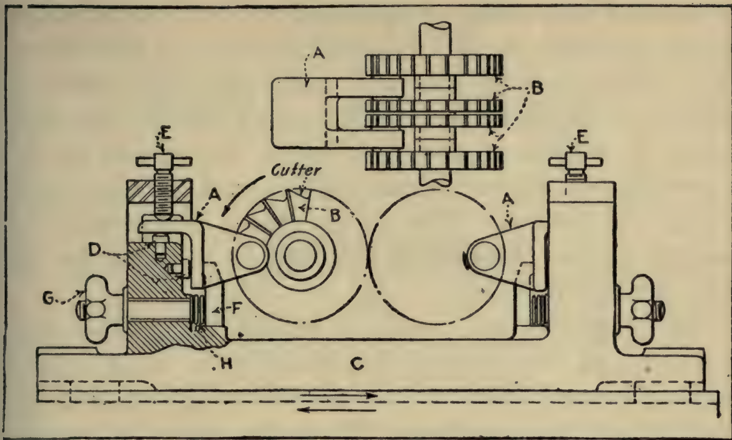


FIG. 66. SIMPLE TYPE OF CONTINUOUS MILLING FIXTURE

while another piece is being machined on the opposite side. The Beaman and Smith Company make a large machine with seven spindles which can be used for continuous milling on large work. These various machines require somewhat different types of fixtures because of their different arrangement of spindles.

In selecting the simplest of continuous milling fixtures, let us look at the one shown in Figure 66, which is made for a horizontal milling machine. The work in this case is a bracket, A, shown in the upper part of the illustration. The bracket is to be straddle milled by a gang of cutters, as shown at B, which are used to face the sides of the bosses as indicated in the upper part of the illustration. The fixture base, C, is located on the table of the milling machine in the usual manner and has at each end a simple type of locating and clamping device in which the work

is located and held. A sectional view of the arrangement is shown at the left-hand portion of the figure. The other end is identical with it. The work is placed in the position shown, resting against the stop pins, D, and is clamped in place by means of the screw, E, at the top of the fixture and by the clamp, F, at the bottom. The latter clamp is operated by means of the thumb nut, G, and is released by the coil spring, H.

In operation, the work is placed in position and clamped on one side of the fixture; the table is then moved inward close to the revolving cutter, and the feed is set in operation. While the table is moving forward and the piece in position is being milled, the operator places another piece of work in position and clamps it at the other end of the fixture. Then, after the work at one end has been completed, the table is moved over to machine the other piece; the first piece is removed from the fixture and another one is inserted in its place. By this description it will be seen that the process of milling is nearly continuous, and for certain classes of work this fixture can be used to good advantage.

Continuous Milling Fixture for Cylinders.—The Beaman & Smith continuous milling machine makes possible the machining of surfaces of large size in such a way that the action of the cutters with properly designed fixtures, is practically continuous from the time the machine starts in the morning until the factory closes at night. The construction of the machine is such that there are a number of tables similar to, but somewhat shorter than, a planer

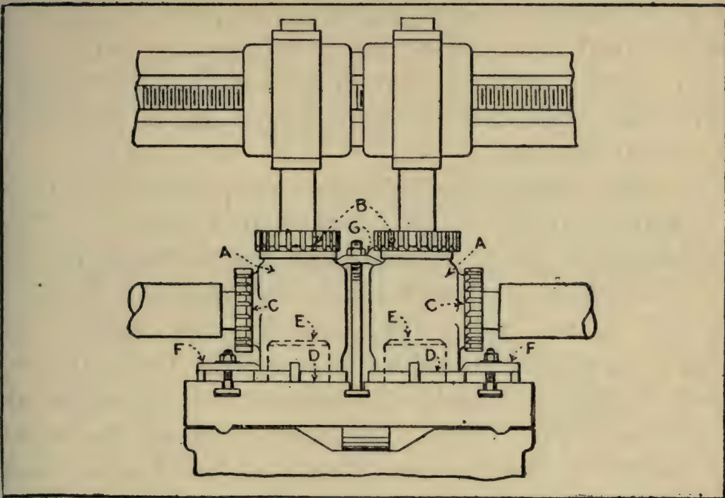


FIG. 67. CONTINUOUS MILLING FIXTURE FOR AUTOMOBILE CYLINDERS

table, and each of these tables can be equipped with a similar set of fixtures. These fixtures can be loaded one after the other and placed in engagement with the feed mechanism of the table, one fixture following the other closely with very little space between. The fixtures pass through the machine from one end to the other, the finished work is then taken off and is replaced by other pieces, after which the entire table with the fixtures mounted on it is carried around to the original starting point and started again on its journey through the machine. For some classes of work four or five of these tables may be required, each with the same type of fixture upon it. In milling the cylinders, transmission cases, and crank cases of automobiles, as well as in other

work of similar character, the production which can be obtained from a machine of this kind is extremely high. Under favorable circumstances from 300 to 400 automobile cylinders of $4\frac{1}{2}$-inch bore can be produced in a ten-hour day.

A good example of a continuous milling fixture for automobile cylinders is shown in Figure 67. The cylinders, A, are to be milled on the surfaces, B and C. They have been previously machined on the end D, and in the bore. The cylinders are located on plugs, E, shown dotted in the bore of the cylinder. Each fixture is capable of holding six cylinders at one time. The fixtures are held down on the table by means of clamps and T-bolts in the T-slots, and the work is held down on the fixture by means of the clamps shown at F and G. In the case shown two milling cutters operate on the upper part of the cylinders and two more opposed to each other are used to machine the surfaces on the sides.

Fixture for "Becker" Continuous Milling Machine.—The Becker type of continuous milling machine uses a revolving table which is in continuous operation after the first pieces have been set in place on the fixture. The fixture, shown in Figure 68, is built to accommodate twelve wall bearings, as seen at A. These bearings are located in position by the fixed studs, B, which act as a vee, into which the pieces are forced by means of the sliding V-block, C, operated by the thumb-screw, D.

After the first pieces have been placed in the fixture, the operator simply removes the finished work and continues to place new pieces in the position

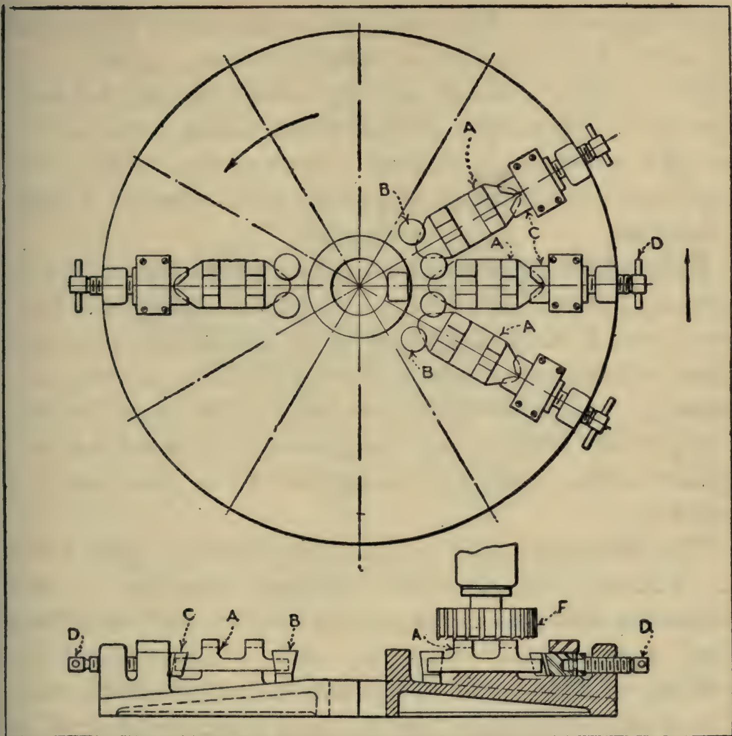


FIG. 68. CONTINUOUS MILLING FIXTURE FOR BECKER MILLING MACHINE

occupied by those just finished. It will be seen that as the cutter, F, is in continuous movement, it has a contact with several pieces at the same time. In the case illustrated the work is of such nature that there is very little "dead time," or time when the cutter is not in contact with the work. This example, therefore, is an excellent one to show the value of continuous milling and how it can be applied to manu-

facturing work. However, when the shape of a piece of work is such that it cannot be set up on a circular fixture without leaving wide spaces between the pieces, it is not advisable to attempt to mill it by the continuous milling process; but with work that can be set close together, it is usually highly profitable.

Spline-Milling Fixtures.—Some years ago the customary method of cutting a slot in a shaft for a key-way was to drill a hole at each end of the slot and then mill from one hole to the other. This process, necessarily, was somewhat slow, and it has been largely replaced by some form of spline-milling machine or a spline-milling attachment applied to a plain milling machine.

The machine that is manufactured by the Pratt & Whitney Co. for this purpose consists of two opposing spindles arranged in such a way that they feed automatically towards each other during the process of the work. The table is reciprocated, with the work in position on it, to a specified length of stroke determined by the length of the key-slot. The fixtures used for this machine may be those which hold a single piece for cutting two slots opposite to each other, or it may be arranged to hold several pieces in which one or more slots are to be cut.

Spline-milling machines are well adapted for all kinds of rectangular key slotting, unless the work to be done is of such a size as to be prohibitory. For all kinds of shafting, arbors, and similar work, it can be arranged without the necessity for any elaborate fixture. In some cases, however, in order to

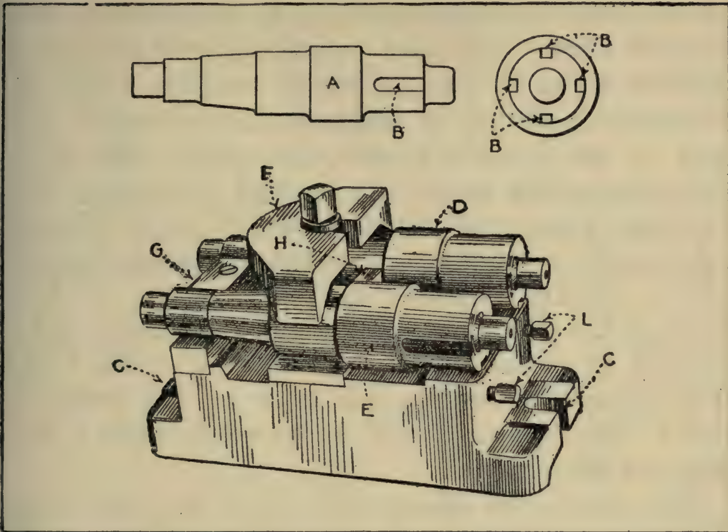


FIG. 69. DOUBLE SPLINE-MILLING FIXTURE

increase production, fixtures may be made to suit particular cases.

A spline-milling attachment for a hand-milling machine, made by the Standard Engineering Co. to apply to one of their hand milling machines, is also very useful for milling key-slots, although but one cutter is used at a time. The attachment is provided with automatic features which make it valuable for many kinds of manufacturing. In the attachment mentioned, the spindle is vertical in relation to the table of the machine. On the spline-milling machine, however, the two spindles lie in a horizontal plane.

Let it be supposed that a piece of work, such as that shown at A, Figure 69, is to be splined or cut

on the end with four keyways, as indicated at B in the end view. This piece having the four slots at 90 degrees apart on the periphery, requires some sort of indexing fixture in order that the various slots may be cut in their proper relations to each other. The illustration shows the method of holding used for this fixture when applied to a Pratt & Whitney spline-milling machine. The fixture base is fastened to the milling machine table by means of bolts through the slot, C, at each end of the fixture, and is aligned by means of keys entering the table T-slot. The method of locating the work on this fixture is out of the ordinary, and is therefore worthy of a detailed description.

The two shafts, shown at D and E, are laid on the finished surface of the fixture. They are held by the clamp, F, the angular portion of which grips and pulls in on the cylindrical part of each shaft. As the clamp screw is set up, the two shafts approach each other until they strike against the finished surfaces or shoulders on two inserted pieces, G and H, which locate and align the work. The first cut on the keyways is made with the pieces set in the position shown, after which the clamp is released sufficiently to permit the two shafts to be turned with the slot downward. A positive method of locating from the first slot which has been cut is provided in the bed of the fixture; and as the shaft is revolved after the first cut and stands with the slot downward on the fixture, this locater engages with the slot and gives positive location. The locaters are controlled by the set-screws, L.

It will be seen that a repetition of the indexing process will produce the four slots at 90 degrees from each other without the need of expensive fixtures ordinarily used for this work. Other examples of spline-milling fixtures will be given, but as they are usually of a simple form which can be made up at minimum expense, it is unnecessary to go into the matter more completely here.

CHAPTER XII

FACE-PLATE FIXTURES

Fixtures for Single Pieces.—In the general process of manufacturing, and also in tool-making, many pieces of work to be machined on an engine or turret lathe cannot be satisfactorily held in any of the various forms of chucks previously described. For such cases either a face-plate of standard form is used, as that shown in Figure 70, or, if a number of pieces are to be machined, a special face-plate with suitable lugs and clamps may be made up. When required for toolmaking, or for a single piece of work, the standard style of face-plate in Figure 70 is commonly employed. This type is made of cast iron and is screwed to the end of the spindle of the machine.

If the toolmaker has a certain piece of work to bore, and the work is of such size that it can be clamped upon the face-plate, he would set up the work against the face of the plate, A, and apply suitable clamps through several of the slotted holes, B, so that the work could be held in the desired position for machining the hole. In setting up a piece of work of this kind he would use an indicator on the work to determine when it was in the correct position for machining. The T-slots, C, can be used

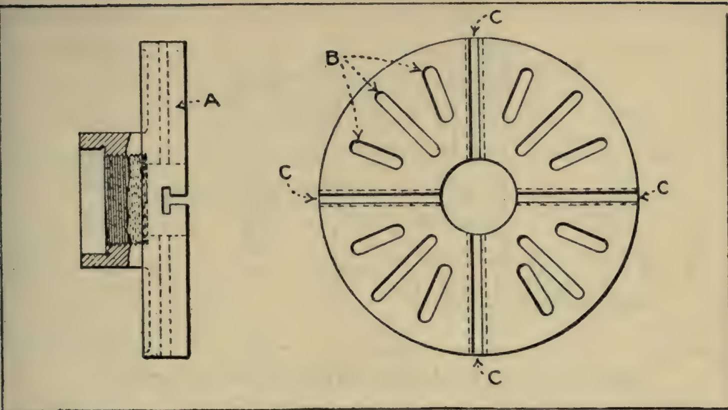


FIG. 70. STANDARD FACE PLATE FOR AN ENGINE LATHE

both to hold the work and to fix steel blocks in certain locations on the face of the plate when several pieces of the same kind are to be machined. Such a face-plate is seldom used in general manufacturing except for the work just described.

Fixtures for Quantity Production.—We now come to the class of manufacturing known as quantity production, where many pieces of the same kind are produced. If a number of pieces are to be machined, it is obvious that the face-plate fixtures to be used can be made up with quick clamping attachments which require a minimum amount of time and labor to set up. They can also be made with simple clamping arrangements which answer every purpose for holding the work but which take a little longer in setting up. The latter fixtures are, of course, somewhat cheaper than the more elaborate, and if the output is to be comparatively low, they will answer every purpose.

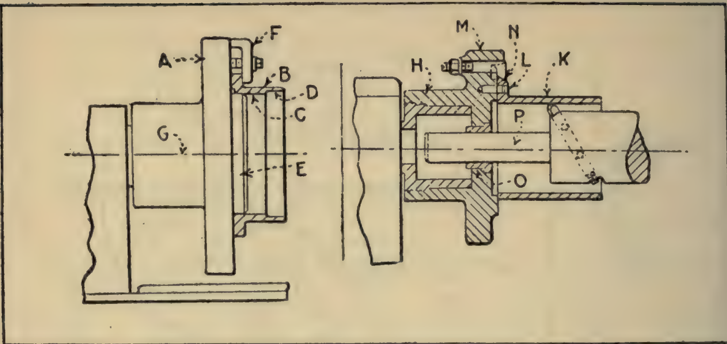


FIG. 71. TWO SIMPLE FACE-PLATE FIXTURES

The fixture, A, Figure 71, is shown holding the work, B, a flanged collar which has previously been machined on its inside surface, C. As it is necessary to cut out the recessed portion, D, of the collar in a subsequent operation, the work is located on the stud, E, and is clamped in place on the locating stud against the face of the fixture by means of the clamps, F, three in number arranged equidistantly on the face of the plate. In a fixture of this kind the revolution of the work around the axis of the spindle, G, is perfectly true, so that when the recess, D, is cut it will be concentric with the previously machined surface, C.

Fixtures for Cutting Packing Rings.—The other example of a face-plate fixture, H, Figure 71, is designed to handle a ring pot, K, from which packing rings are to be cut. The ring pot has previously been faced on the end shown against the face-plate and three holes have been drilled in the flange for locating and driving purposes. The work is set up

on the face-plate fixture, locating on the pins, L, one of which is shown in the illustration. The work is clamped back against the face of the fixture by means of three hook bolts, M, having an angular end which engages with the angular flange at N, thus holding the work back firmly against the face of the plate. This face-plate is provided with a bushing, O, in which the pilot, P, of the boring bar is guided. The boring bar is used to bore out the inside of the pot, as indicated. When a number of packing rings are to be made up a fixture of this kind can be used to advantage or the flange of the pot can be made so that it can be gripped in chuck jaws of special form. The latter method is more common at present and is superior to that shown, due to the fact that no preliminary operation is necesary on the work before this machining operation.

Face-Plate Fixture for a Hub Flange.—The face-plate fixture shown in Figure 72 is somewhat similar to that noted at A, in Figure 71; but in this case the work is located by an outside surface which also has been previously machined, shown at A in this illustration. The face-plate, B, is screwed to the end of the spindle as indicated, and is recessed to allow the shoulder, A, to fit into it, thus giving the correct location. The flange, C, has been drilled in several places, as indicated at D, and these drilled holes are used for driving against the pressure of the cut, by means of the pins indicated. The clamps, E, three in number, hold the work back against the face of the plate, and are slotted to allow them to be drawn off the flange when setting or removing the work

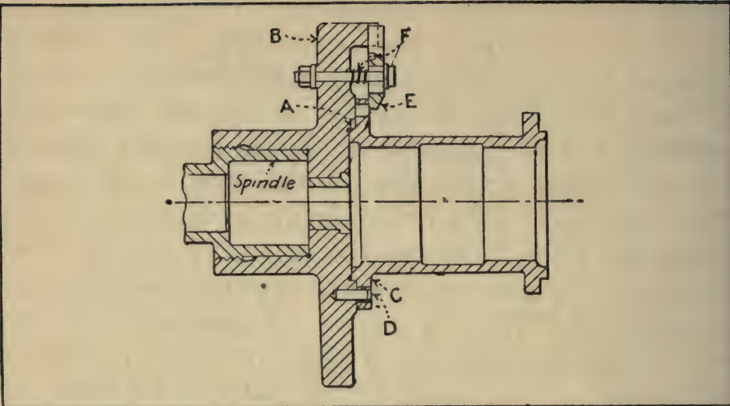


FIG. 72. FACE-PLATE FIXTURE FOR A HUB FLANGE

from the fixture. The coiled springs, F, are provided in order that the clamps will always stand away from the work when it is being placed in position. Fixtures of this kind, largely used in the general process of manufacture, can be adapted to many kinds of turret lathe work.

Self-Centering Fixture for a Rough Casting.—It is sometimes desirable to machine a piece of work, a ring pot, for instance, whose shape is such that it is not readily held in chuck jaws. A fixture for this purpose is shown at A, Figure 73. The casting, B, is somewhat thin in section, and is to be bored and turned by means of the tools, C and D. As no previous machining has been done on the casting, it is necessary to center it from the rough surface in some way and to clamp it firmly on the fixture.

For the purpose of centering the work, a spring tapered plug, E, is located in the fixture in such a

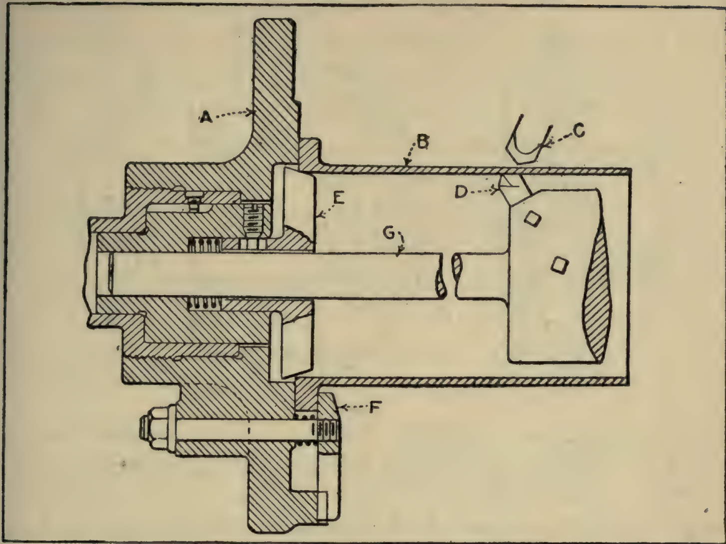


FIG. 73. SECTION THROUGH A SELF-CENTERING FIXTURE FOR A RING POT

way that it automatically centers the work from the inside. The spring at the base of the plug permits the clamps, F, to be tightened down upon the face of the flange, so as to grip the work securely. While the spring plunger centers the work, it does not in any way prevent the tightening of the clamps, and also it is bored out and ground to the size of the pilot, G, of the boring bar in which the cutter, D, is located. The principle used in this fixture can be applied to a variety of work on turret lathes and boring mills.

Fixture for Thin Aluminum Castings.—The instances which have been previously noted have all been pieces of cylindrical section, but it frequently

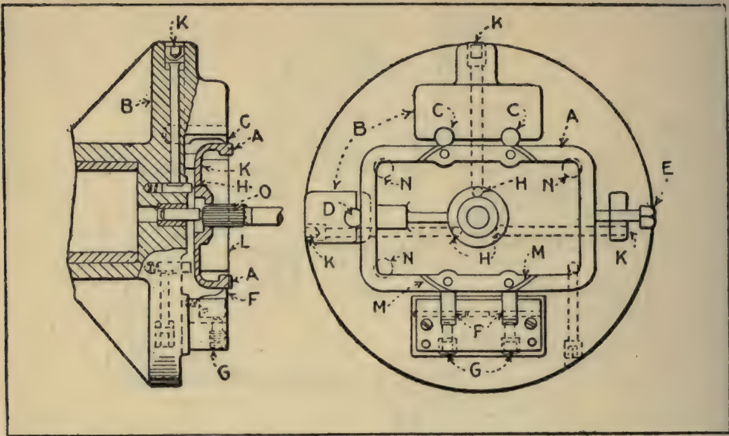


FIG. 74. FACE-PLATE FIXTURE FOR A THIN ALUMINUM CASTING

happens that the work which is to be machined is of irregular form requiring special arrangements for locating and holding it. One point in the design of face-plate fixtures for such work, is that the piece shall be held in such a way that it will be firmly secured and will not be distorted in any way by imperfect clamping. An example is shown in Figure 74, where the work is an aluminum casting, A, of more or less rectangular shape.

The V-principle, so-called, in locating work on fixtures of various kinds, is based on the fact that a piece of work can be put into a V-shaped block or its equivalent in such a way as to act as a locater whether the piece is a rough casting or one that has previously been machined. It might almost be said that the basic principle of jig and fixture design is that of locating by means of a form that resembles the

capital letter V—generally written, vee. This vee form is often obtained by means of a series of pins arranged in proper formation to receive the work.

In the instance noted in Figure 74, the work, A, is placed on the fixture, B, in such a way that it locates against the fixed steel pins, C, on one side of the fixture and the pin, D, on the other which form a sort of vee. The work is forced over against the pin, D, in one direction by means of the screw, E; while the location in the other direction is performed by means of the swinging clamp, F, operated by the hollow set-screws, G. It will be seen that the swinging clamps, F, have a knife edge and that the locating pins at C and D are similarly arranged. The purpose of this arrangement is to sink these clamps and pins into the surface of the casting slightly, so as to keep it from being pulled out while the piece is being machined. As the bottom of the casting is also rough, it must also be supported, so that the work will not be pushed inward toward the face of the fixture by the pressure of the cut. This is taken care of by means of the spring pins, H, which adapt themselves to the rough surface of the casting and are firmly locked in position by the set-screws, K, in the outer rim of the face-plate. In addition to the spring pins, H, the work is given a positive location on the fixed pins, N, at three corners of the piece.

The work which was done upon this casting after it was located and clamped, was the facing of the surface, L, the turning and sizing of the interrupted circular tongue, M, and the boring and reaming of the center hole with the reamer, O. The machine on

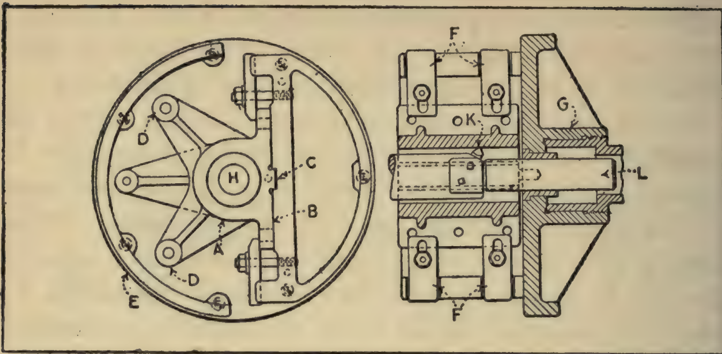


FIG. 75. PLAN AND SECTION OF A FIXTURE WITH SAFEGUARDING DEVICES

which this work was done was a horizontal turret lathe, and the equipment for producing the work was of a special nature. The principles shown in this fixture may be applied to many other examples of turret lathe work.

Fixture for an Irregular Bracket.—The protection of workmen engaged in manufacturing is often neglected in the design of fixtures for turret lathe work and other work that requires similar handling. It should be the purpose of every designer to make any fixture upon which he is engaged so that it will be impossible for a workman to become injured by it. It happens occasionally that a piece of work with projecting arms or lugs is to be held on a face-plate fixture, and when such cases of this kind arise the designer should exercise the greatest care to make the fixture in such a way that the workman will be protected from these projections as they revolve.

An example of this kind is shown in the piece of

work, A, in Figure 75. This piece has been previously machined by milling the surface, B, and cutting the tongue, C. It will be seen that the bracket has three projecting arms, D, which, if unprotected, might strike a workman when machining the piece. The fixture, therefore, is made up with a protecting rim, E, of such height that the arms do not extend beyond it. The extra cost of making a fixture like this is very slight, and in addition to the safety feature, the rim, E, also acts as a counterpoise and makes the fixture run more smoothly.

The work is located on the fixture against the finished pads, D, and the tongue, C, lies in a groove provided for it. The work is clamped by means of the four straps, F, which are slotted so that they can be moved back to allow the work to be set up and removed. As in the preceding instance, the body of the fixture, G, is screwed to the nose of the spindle, as indicated. The work to be done in this case is the boring of the hole, H. This work is performed by means of the tool, K, mounted on a bar whose forward end is piloted by a bushing, L, in the face-plate fixture. This method of piloting a boring tool or other cutting tool assists greatly in producing accurate work, as the bushing acts as a guide for the bar and keeps it always in a certain relation to the work.

Counterbalanced Fixture for a Connecting Rod.—For a piece of work that is very much off center and is to be bored or otherwise machined at high speed, it is often necessary to provide a counterbalance on the fixture in order to prevent excessive

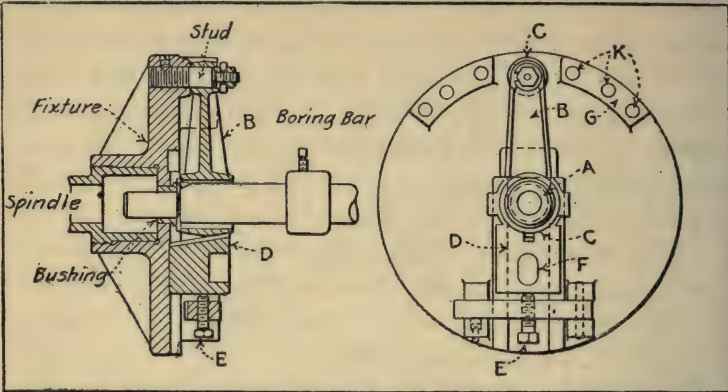


FIG. 76. COUNTERBALANCED FACE-PLATE FIXTURE FOR A CONNECTING ROD

vibration from the unevenly balanced rotation of the work and fixture. An example is shown in Figure 76. The fixture here is designed for boring and reaming the hole, A, in the connecting rod, B. The connecting rod has been previously drilled and reamed at the small end, C, and it is necessary to locate it for the remaining operation in such a way that the hole, A, will be in a fixed relation to the previously reamed hole, C. The face-plate fixture, therefore, is made up with a stud on which the portion, C, locates. This portion of the work is drawn back against the face of the fixture by means of a nut. The large end is then correctly located by means of a V-block, D, which centers the boss at C. This V-block is undercut, as indicated in the sectional view, so that it tends to draw the work back against the face of the plate, when it is then set up by means of the screw, E. This screw is mounted in a swinging latch and

can be thrown back to allow the workman to hook his finger into the recess, F, and pull the block away from the work.

As the fixture is considerably heavier on one side than on the other, provision is made for counterbalancing it by means of the lugs, G. These lugs are a part of the cast-iron face-plate and are made heavy enough and thick enough to more than balance the mechanism on the opposite side of the fixture.

In balancing a fixture of this kind, the work is placed in position and all clamps are set up as if the machining was about to be done. The fixture is then placed on an arbor and allowed to swing as it will. Naturally, the heaviest portion will hang downward. The workman then drills out a portion of the stock from the lug, as indicated by the holes, K, and tests the fixture again, continuing the operation until a proper balance is obtained. Sometimes so much stock has been added as a counterbalance that it becomes necessary to mill off a portion of the counterpoise in order to bring the fixture into balance.

Fixture with Adjustable Counterbalance.—A fixture for turret lathe work or for the engine lathe may be needed which will enable several pieces of similar character to be machined upon it by making slight modifications. An irregularly-shaped piece of work which has a counterbalanced portion, will permit the counterbalance to be shifted radially on the plate so that it will balance whatever piece is being held upon it. An example of this fixture is shown in Figure 77.

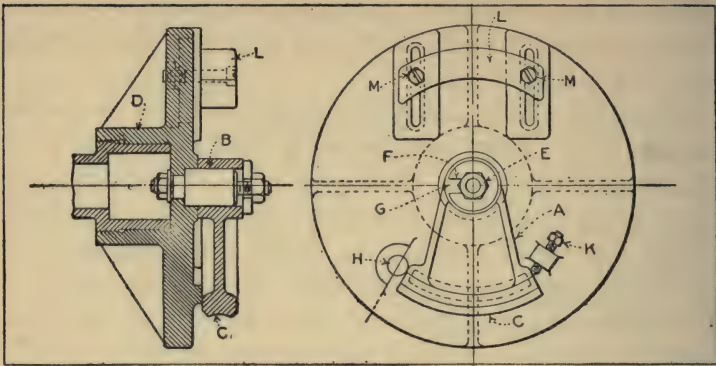


FIG. 77. SECTION AND PLAN OF A FIXTURE WITH ADJUSTABLE COUNTERBALANCE

The work in this case is a worm-gear sector, A, which has been previously bored and reamed at B, and now is to be machined as indicated at C. The work is located on a fixed stud at the center of the fixture, and is clamped back against the finished pad by means of the nut, E. A "C-washer," F, is used with the nut so as to permit the work to be removed rapidly. By using such a device it will be seen that the nut can be slightly loosened, the C-washer slipped out through the slot, and the work immediately released without removing the nut, E.

In order to provide the portion of the work, C, with a rigid support, it is swung around against the stop pin, H, and is clamped by the screw, K. As this side of the fixture, then, is so much heavier than the other, it is necessary to provide a counterbalance at L. This counterbalance is in the form of a segmental block with two bolts through it, as indicated at M, which pass through the two slots, and

allow the counterbalance to be radially adjusted to compensate for pieces of different size. An application of this principle of a movable counterbalance can be made to many types of lathes, turret lathes, and other machines of similar character. In cases where the work to be machined is of comparatively large diameter, so that the work runs at slow speed, it is not usually necessary to counterbalance it.

Eccentric Fixture for a Ring Pot.—In making up packing rings for automobile motors, compressors, and the like, an eccentric ring is frequently desirable. The ordinary process of machining one of these is by means of an eccentric turning device which will be described in Chapter XIV. As an eccentric device of the character mentioned is somewhat expensive, however, the small manufacturer frequently dispenses with such a device and handles the work in a slightly different manner. But when the device is employed, the work is turned eccentrically by means of the device and is also bored concentrically at the same time, thus saving a considerable amount of time in the process.

When an attachment of the kind mentioned is not used, it is customary to bore the work in one operation. The outside eccentric is then turned in another operation, either by means of an eccentric arbor or by placing the pot from which the rings are to be made on a fixture which can be set eccentrically after the hole has been bored.

In Figure 78, the ring pot, A, is located on the face of the fixture by means of the lugs and clamps shown at B. The face-plate consists of two parts, one of

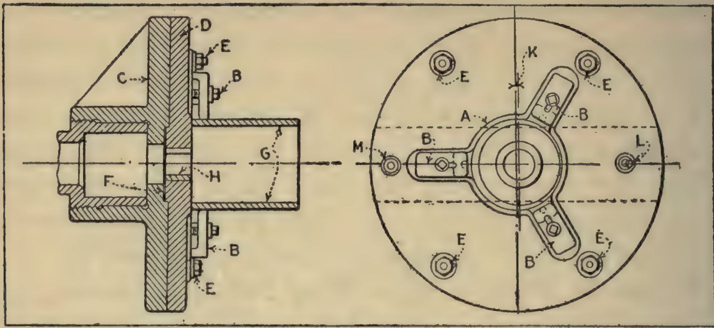


FIG. 78. ECCENTRIC FIXTURE FOR A RING POT

which, C, is screwed to the end of the spindle, and the other, D, is fastened to it by means of the bolts, E, which enter slotted holes in the plate, D, to allow for a slight movement of the upper plate on the lower. The plate, C, is grooved at F, directly across its face; and the plate, D, is provided with a tongue to slide in this groove.

In operation, the hole, G, is first bored by a boring bar piloted in the bushing, H, in the movable plate. After this operation has been done, the nuts at E are loosened and the plate is set over the amount indicated by the line at K. The correct distance is determined by pins and bushings at L and M.

This type of eccentric fixture is very simple and answers all purposes for work of this character. It is unnecessary to counterbalance the fixture unless the eccentricity is so great that the fixture runs out of balance when it is set over.

Swinging Eccentric Fixture.—A fixture may be required that will permit a slight amount of adjustment so that it can be set to give two or three eccen-

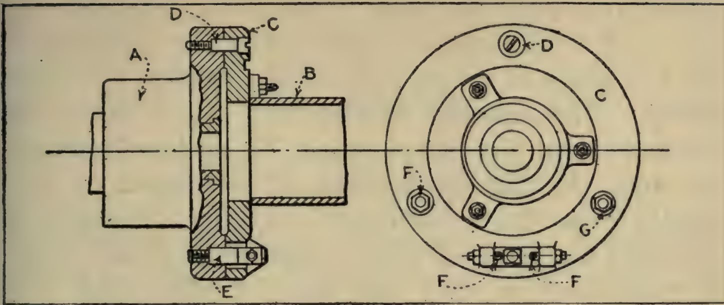


FIG. 79. PLAN AND SECTION OF A SWINGING ECCENTRIC FIXTURE FOR A PACKING RING POT

tricities. In order to provide for a contingency such as this it is necessary to make the fixture so that the stops which limit the throw of the eccentric are adjustable. An example of such a fixture is shown at A, Figure 79. The fixture is designed for a horizontal turret lathe for boring and turning eccentrically the work, B. The ring pot, B, which is to be turned and bored, is held on the plate, C, in practically the same way as the pot shown in the previous illustration. The mounting of the plate on the body of the fixture, however, is arranged in a different way. In this case, the plate is pivoted so as to swing from the stud, D. The lower portion of the body plate, A, is provided with a stop extending out through a slot in the plate, as indicated at E. Adjusting screws, F, on the surface of the fixture at E, provide for lateral movement of the plate, and suitable clamping bolts, G, on each side of the fixture hold it in place.

When it is desired to set over the work to produce the eccentric, the bolts, G, are loosened and the plate

swung over until the stud, E, strikes against the set-screws, F. The amount which these set-screws permit the plate to move, govern the amount of eccentricity. The spacing of the stop, E, is twice the distance from the pivot point, D, to the center of the work, so that the amount of movement at F is exactly twice the eccentricity produced. Fixtures of this kind can be used with success on a great variety of work, and as they are cheaply made and very serviceable they may be considered as excellent types of eccentric turning and boring equipment.

CHAPTER XIII

ARBORS AND MANDRELS

Definition of Terms.—The term arbor is applied to the cylindrical piece used for mounting cutters upon a milling machine. It is also applied to the device used to center a piece of work by a previously bored or reamed hole so as to bear a distinct relation to the hole. The term mandrel is almost synonymous with the term arbor as applied to holding work. For example, the expressions, "an arbor for a ¾-inch hole," or "a mandrel for a ¾-inch hole," are used interchangeably. The term mandrel, however, is not used synonymously with the term arbor when applied to the device for holding cutters in a milling machine. These would always be referred to as "cutter arbors."

Arbors are of several kinds—plain arbors, threaded arbors, expanding arbors, and cutter arbors. The last mentioned is generally used in the milling machine for holding one or more cutters in position. This type of arbor is quite simple and is variously made as a part of the standard equipment for a milling machine. Such an arbor is shown in Figure 80 at A. The tang end, B, is tapered to fit the milling machine spindle, and may be used in an adapter when the spindle taper and that of the arbor do not

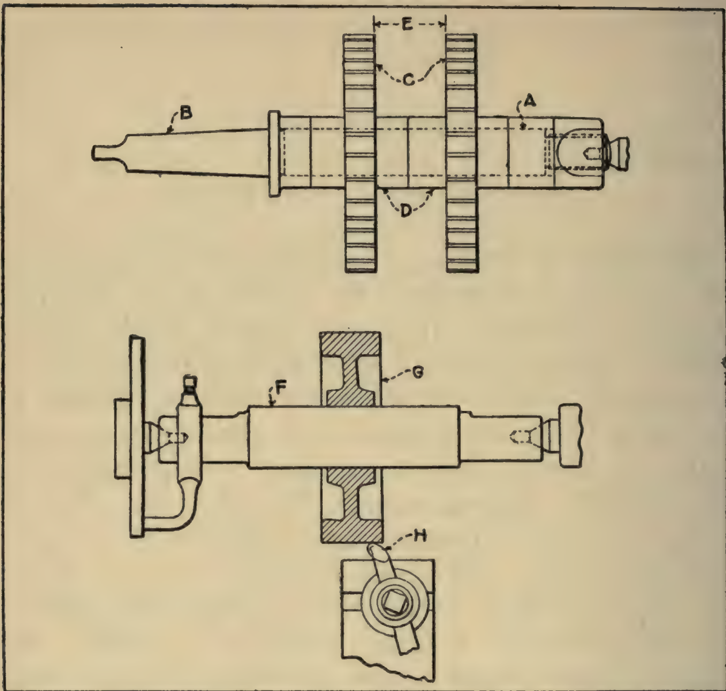


FIG. 80. ARBOR FOR MILLING MACHINE, ABOVE, AND FOR PLAIN LATHE, BELOW

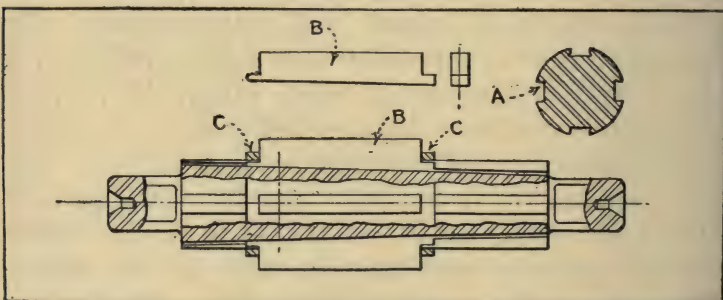


FIG. 81. EXPANDING SHOE TYPE OF ARBOR
W. H. Nicholson & Co.

correspond. The cutters, C, are placed on the arbor with one or more spacing collars, D, between them to space the distance, E, correctly for the work required. There is little to be said about milling machine arbors as their design is so extremely simple.

A plain arbor or mandrel, indicated at F, Figure 80, is usually found in the tool crib in all standard sizes. It is made up for standard sizes of holes, usually with a taper of about 0.006 inch per inch of length. When a piece of work, such as that shown at G, is to be turned on its surface by the tool, H, after it has been reamed in a previous operation, it is placed under an arbor press and the arbor, F, is forced into it under pressure. As the arbor is tapered, it will wedge firmly into the work so that there will be no slipping when the pressure of the cut is applied. Arbors of this kind are usually designed to be dogged to the face-plate, as indicated in the drawing.

Arbor with Expanding Shoes.—It is often necessary to hold a piece of work that is slightly over or under a standard size on an arbor, to perform some operation upon the piece which will be absolutely concentric with a previously finished hole. Two methods of holding are possible. The toolmaker or machinist can make up, in comparatively short time, such an arbor as that shown in Figure 80, of such a size as to suit the hole in the work. Or, if the tool crib is well equipped with expanding arbors, it may not be necessary to make up a special one for the job.

Expanding arbors are of several types, but perhaps

the most useful type is that shown in Figure 81. Such an arbor can be purchased in various sizes to suit any given conditions. The body of the arbor is hardened and ground to cylindrical form. It is furnished with four slots, A, into which are fitted the shoes, B. It will be noticed that the slots are cut on a slight longitudinal taper, so that when a piece of work is placed on the shoes, they may be adjusted along the tapered slots to the required diameter. The retaining ring, C, at each end of the shoes are slotted to receive the shoes and hold them on the arbor when not in use. This type of expanding arbor should form a part of the tool crib equipment and should be bought in a sufficient range of sizes to cover the requirements of the class of work which is being done. This same type is also largely used in general manufacturing, and its adaptability suits it for an infinite number of pieces.

Split Ring Expanding Arbor.—It is sometimes necessary to refinish the outside of a piece of work and make sure that it is absolutely concentric with the center of the hole that has been previously machined. A common type of arbor for this purpose is shown in Figure 82 at A. Let it be supposed that the work, B, is to be held by the hole previously finished in it, and that the work is to done on an engine lathe. A steel arbor, C, is then made up with a slight taper along its length. A sleeve, D, is split along its length at E, and is tapered on the inside so as to fit the taper on the arbor, C. When the work, B, is placed in position and forced onto the arbor over the split ring, the ring expands slightly as it is forced up on

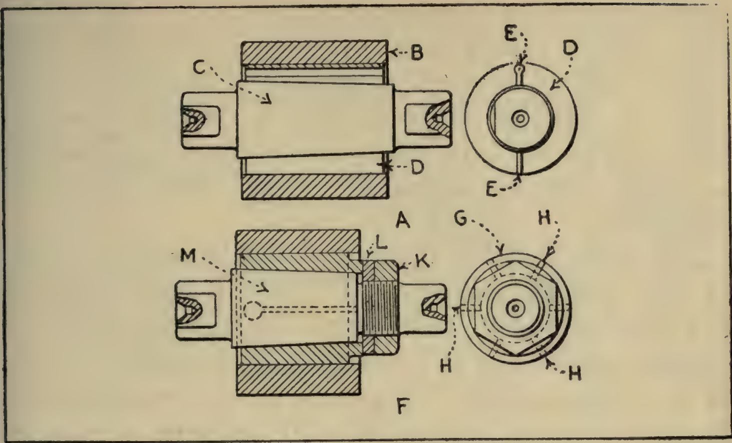


FIG. 82. SPLIT-RING EXPANDING ARBORS

the taper until it grips the work securely, thus holding it so that it can be machined readily. This type of arbor is not exceptionally good, as it is simply split longitudinally. When it opens up, the ring, D, therefore, is slightly elliptical and does not expand evenly all over. As a cheap arbor that can be used for a few pieces, such a device will answer the purpose in many instances, but it should not be used for work requiring great accuracy.

A much better type of arbor, shown at F, can be used for work requiring great accuracy. Roughly, the principle of the two arbors is the same, except that in the instance previously mentioned the ring is split in one direction only, while in the example, F, the ring, G, is split longitudinally into three slots, running from one almost to the other and spaced 120 degrees apart, as indicated at H. There are also

three other slots starting from the other end of the ring, spaced equidistantly between the slots mentioned, and also running nearly to the end of the ring. It will be seen that this arrangement allows the ring to be expanded equally all over, making a much better construction than that previously described.

An additional requirement on this arbor is seen in the nut, K, and washer, L, by means of which the ring is forced back on the taper, M, so that it expands and holds the work. In the example shown at A, it is necessary to use an arbor press to force the work on, or else to drive it on with a piece of babbitt or wood. For finishing the outside of collars, small blanks, and other work of similar character, the type of arbor shown at F is very useful, and is frequently found among the tools used for general manufacturing.

Expanding Arbor for an Automobile Flange.— Special arbors may be made up to suit a particular case when a number of pieces are to be manufactured. One such is shown in Figure 83. In this case the work, A, is an automobile flange which has been previously bored and reamed at B and C. As it is necessary to finish the end, D, and the flange, E, the method of holding by the inside surface was devised.

The machine to which this arbor was applied is a horizontal turret lathe. The method of holding was by means of the collet mechanism with which the turret lathe is furnished, the stem of the arbor, F, being held as indicated in exactly the same

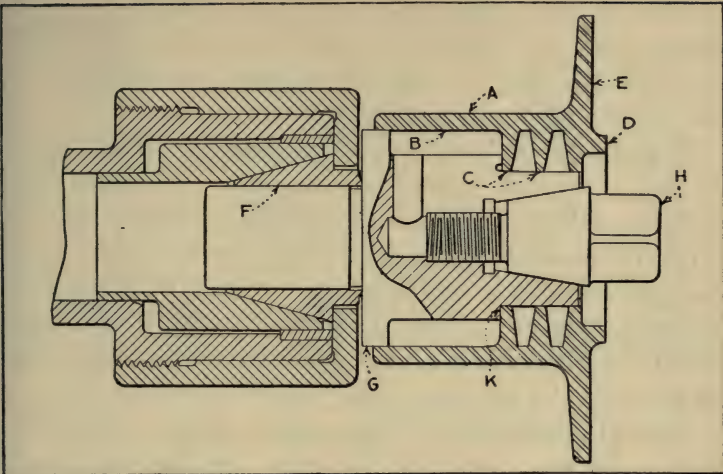


FIG. 83. SECTION THROUGH EXPANDING ARBOR FOR AN AUTOMOBILE FLANGE

manner as that used to hold a piece of bar stock. The work then was placed on the portion, G, which made a nice fit at this point. After the work was so placed, the tapered screw, H, was set up, thus expanding or opening up the arbor to grip the points, C. A shoulder was also provided on the arbor to give longitudinal location at K.

When making use of the collet mechanism to hold an arbor for manufacturing purposes, it is necessary to make sure that the collet is perfectly true; otherwise the arbor might run out of truth and work might be produced which would not be concentric.

An arbor of this kind must be made of tool steel, tempered slightly in order that it may expand properly and come back to place again when the tapered screw is released. It will be understood that the

portion of the arbor which is controlled by the expansion of the tapered screw, is slotted into three sections, so that it can be opened up slightly by the action of the screw mentioned.

Expanding Arbor for an Adjusting Nut.—Occasionally several pieces of similar character but slightly different in size may be machined by the same or similar equipment on a turret lathe. An example is shown in the pieces A and B, Figure 84. These pieces are bronze adjusting nuts in two sizes, slightly different both in outside diameter and in the location of the spanner holes shown at C.

Several thousands of these parts were to be made, and as it was desirable to make up the equipment as cheaply as possible, the arbor was so designed that it could be used for both pieces by the aid of an adapter. A special nose piece, D, was screwed to the end of the spindle, as indicated, shouldered at E to receive the ring, F, which was used for the piece, A, and also could be fitted with the ring, G, for use with the piece, B. In each case the rings were provided with pins, H and K. These pins entered the spanner holes, as indicated, and assisted in driving the work—an essential point in connection with an arbor on which any heavy work is to be done. The outside of the nut in each case was to be threaded with an opening die, so that the pulling action of the cut was rather severe.

A split ring, similar to the one shown at G, Figure 82, was used to center the work. This ring, of course, was very much smaller than the one previously mentioned, but the method of splitting was the same.

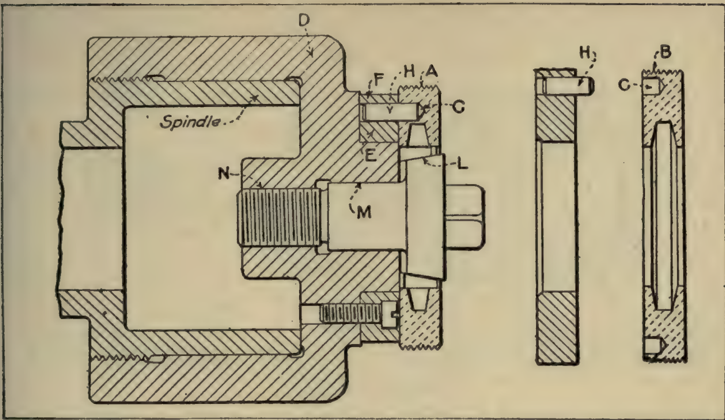


FIG. 84. EXPANDING ARBOR FOR AN ADJUSTING NUT

In this arbor, it will be observed, expansion was procured by means of the tapered plug, L, which had a generous bearing, M, in the nose piece. The threaded portion, N, was somewhat loose in order that the centering action might not be governed by the threaded portion, but might be absolutely determined by the cylindrical part, M. The thread was simply used as a means of drawing in on the plug and thus expanding the ring at L.

Applications of this principle may be made to many kinds of narrow work when it is necessary to do heavy cutting on the outside. It occasionally happens that one or more holes are drilled in a piece of work in order to provide a means of driving. In the particular case mentioned, the spanner holes, fortunately, made this unnecessary.

Expanding Arbor for a Bevel Pinion.—It is particularly necessary to machine a bevel pinion in such

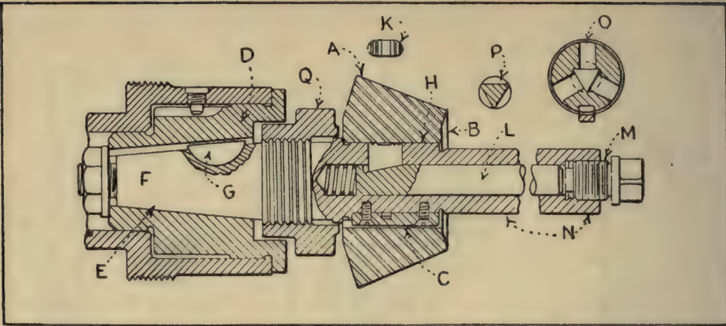


FIG. 85. SECTION THROUGH EXPANDING SHOE ARBOR FOR A BEVEL PINION

a way that the outside of the gear is in perfect concentricity with the hole. In order, therefore, to provide a means by which such an effect may be secured, it is necessary at times to design an arbor of small dimensions with adjustable features to provide for self-centering.

Occasionally, also, the kind of tooling which is to be used on a piece of this kind has a certain effect on the design of the arbor. Such an instance is shown in Figure 85. This is an unusual type of arbor for it is somewhat delicate in construction. Its mechanical features, however, are of considerable value, and the principle shown may be applied to other work of similar character.

This arbor was made up for use on a horizontal turret lathe in connection with a special taper attachment for generating the angular surface of the pinion, A, which had previously been bored and reamed on another machine. At the same setting of the work, the face, B, was to be machined. Pre-

vious to the operation shown and after the hole had been reamed, a keyway, C, was cut in the pinion in order to provide an efficient means of driving while the heavy cutting was taking place at A. The spindle of the machine was provided with an adapter, D, which had a tapered hole, E, where the stem, F, of the arbor was located. A key driver, G, was also added to make the driving positively certain.

As will be seen from the illustration the work located on the cylindrical surface, H, which was made 0.002 of an inch under the size of the hole in the pinion. There are three slots cut in the arbor to receive the shoes, K, which were beveled slightly on their internal faces so as to fit the taper on the operating rod, L. This operating rod was pushed back into the arbor by means of the screw, M. The portion, N, is ground to fit a shell mill held in the turret and used for facing the angular surface, B. As the operating rod was pushed inward by means of the screw, M, the three shoes, K, were forced outward against the inside of the hole in the pinion, thus providing an efficient centering action. A sectional view, taken directly across the arbor and through the slots, is shown at O, and a corresponding section of the operating rod is indicated at P.

Although an arbor of this kind is fairly expensive and rather delicate in its construction, it may be used in a number of cases where the greatest accuracy is necessary. The equipment mentioned is really the "last word" in the design of an accurate expanding arbor. An additional refinement is found in the knurled nut, Q, which is used to start the

work after it has been machined in the event that it might stick slightly.

Expanding Pin Chuck for a Piston.—Automobile pistons, A, Figure 86, and certain other classes of work, are made in such form that the inside portion is "cored." A core, if of large size, but not extending completely through the work, always shows a tendency to sag more or less while the casting is made, so that the resulting work is not absolutely concentric. This is particularly true of automobile pistons. Therefore, such work must be held in such a way that when it is machined on the outside, the surface will be very nearly concentric with the inside rough-cored surface, no matter whether the casting is true when in the rough state or not.

It is logical to hold such work for the machining processes from the inside core, so as to be sure of the concentricity. This method of holding makes necessary a rather elaborate arbor. Arbors made for this purpose are of various forms, each having some particular claim for its existence. The example shown in Figure 86 is one of the best for this class of work, and has been built to suit numerous cases with the most satisfactory results. It is by no means a cheap arbor, and it requires the greatest care in design and the most careful workmanship in machining. Yet its action is so satisfactory that in the event of a large number of pieces to be machined, the first cost of the arbor may almost be neglected.

The arbor, shown at B, is screwed to the end of the spindle, as indicated. It is made of machine steel, carbonized, hardened, and ground in its essen-

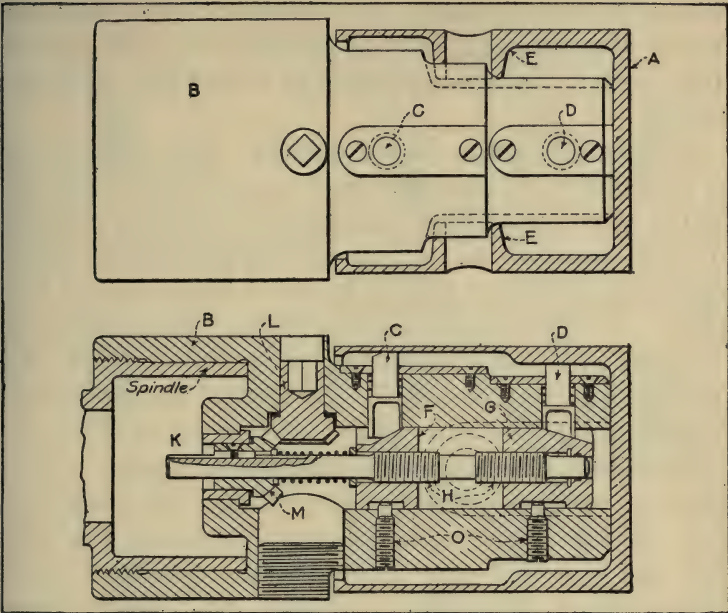


FIG. 86. PLAN AND SECTION OF EXPANDING PIN CHUCK FOR A PISTON

tial parts. Six pins are so spaced as to be equidistant around the periphery at C, while at D they are arranged in such a way as not to interfere with the wrist pin bosses shown in the upper sectional view at E. The lower ends of the pins are beveled to ride on the two cams, F and G. These cams are threaded right and left hand to fit the screw, H, which is provided with a slot, K, for operating purposes—a pair of bevel pinions, at L and M, being used as the operating means. It will be seen that when the pinion, L, is revolved by means of a special socket wrench, the motion is transferred to the

pinion, M, which turns the threaded shaft, H, and causes the cams, F and G, to approach or recede from each other according to the direction of rotation.

A valuable point in connection with this piece of mechanism is the fact that the pressure exerted on the pins C and D is equalized, so that the amount of force exerted on all six pins is the same. This equalizing action is caused by the "float" in the two cams. As the shaft, H, is free to move slightly longitudinally, the pressure is distributed on the two cams in an equal ratio. The cams are prevented from turning by means of the set-screws, O.

Threaded and Knock-off Arbors.—Tapping out a piece of work in such a way that the threaded portion will be in perfect concentricity with the outside and with the ends of the work, is a difficult operation. It is, therefore, necessary to provide some means of re-finishing the outside of the work or the ends, using the threaded portion as a locating point. The simplest type of arbor which can be devised for holding a piece of threaded work is that shown at A, Figure 87. In this arbor a portion, B, is threaded to receive the work, which is screwed upon it and makes up against the shoulder, D.

This arbor is held on centers in an engine lathe and is driven by means of a dog in the usual manner. While it will give satisfactory results, it is by no means a convenient type to use, for the reason that the pressure of the cut in finishing the outside of the work is such that it causes the piece to "freeze" up against the shoulder, D, so that it is

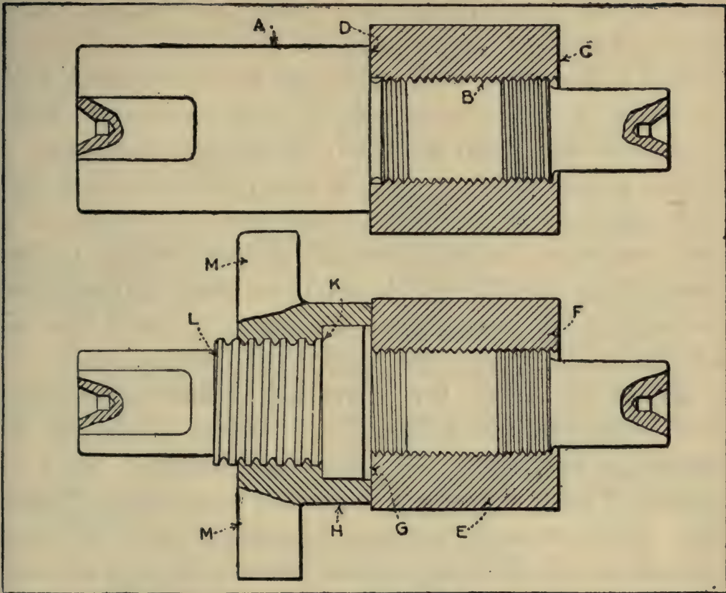


FIG. 87. THREADED AND KNOCK-OFF ARBORS

difficult to remove it without the use of a pipe wrench or special clamps.

A much better type of arbor and one which overcomes this trouble, is shown at E in the lower illustration. This arbor is threaded in the same manner as the upper one in Figure 87, except that the work, F, does not make up against the shoulder, G, but rather against the flange, H. This flange, however, fits against a shoulder, K, on the arbor, so that the longitudinal location of the work always comes the same.

Provision for removing the work without difficulty is as follows: The arbor is threaded, at L, with a

coarse left-hand thread on which the flange, H, is screwed until it strikes against the shoulder, K. The flange is provided with two lugs, M, on opposite sides in order to make the matter of releasing easy. When the work has been finished, it is only necessary to strike either of these lugs a sharp blow with a babbitt hammer or piece of wood and the work is at once released, because the end of the work is backed away from the flange, H. It is an easy matter, then, to release the piece from the arbor without the aid of any tools except the workman's hands.

Knock-off Arbor for Threaded Collars.—An excellent example of a knock-off arbor designed for handling a number of pieces of threaded work of different sized threads and pitches is shown in Figure 88. There were a number of collars such as those shown at A, B, and C; the manufacturing requirements of which made it necessary to have the ends square with the thread. An equipment was designed, therefore, so that by means of adapters, such as those shown at D, E, and F, and with threaded arbors as that shown at G, a number of different sizes could be handled with little trouble. A master bushing, H, was inserted in the spindle of a turret lathe, as indicated. In it the adapters, G, were located by means of the taper at K, and were drawn by a bolt, L, provided with a spherical washer, M, in order to equalize any strain caused by the action of the bolts in drawing the work back into the taper, K. The master bushing was provided with a threaded portion, N, and a shoulder, O, against which a plate, P, gave the correct location to the work. The threaded

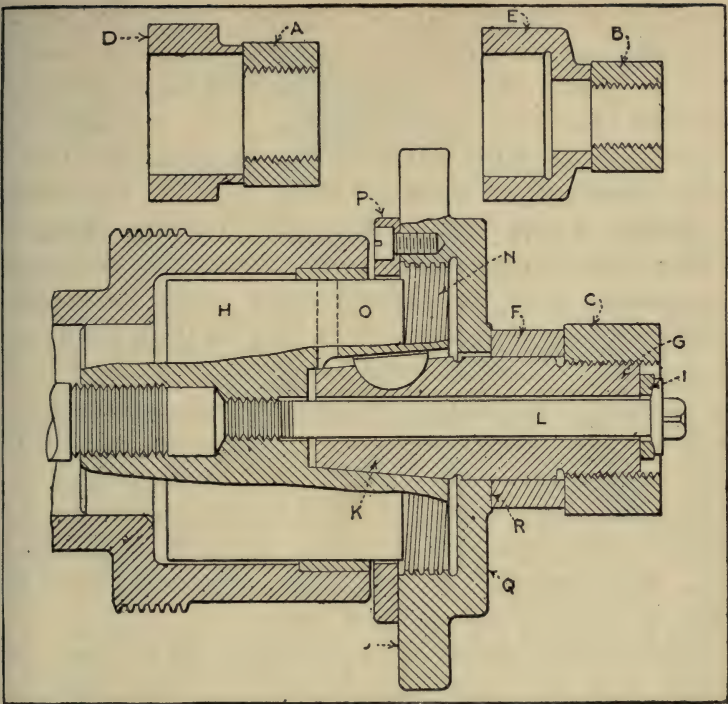


FIG. 88. KNOCK-OFF ARBOR FOR THREADED COLLARS

portion was made left hand, as in the preceding instance. A knock-off flange, Q, was made with a finished pad, R, so that a spacing collar, F, could be used in connection with the work.

In operation, the threaded flange is screwed up until it makes against the shoulder at O; the spacer, F, is inserted, and the work, C, is screwed onto the arbor. Then, after the machining has been done, the lugs, S, are given a sharp blow with the hammer or a block of wood, and the work is immediately

released so that it can be removed from the arbor. I made up an equipment of this kind to handle twelve pieces of different diameters and different threads, and its operation was very satisfactory. Moreover, the same principle may be applied in many other cases where threaded work is to be machined.

Special Arbor for an Eccentric Packing Ring.—The packing ring, shown at A, Figure 89, is a type commonly used for compressors and automobile motors. The operations on a ring of this kind are as follows: A pot casting is first made up and held in such a way that it can be turned eccentrically and bored at the same time. In the same operation the rings are cut off from $\frac{1}{4}$-inch to $\frac{3}{8}$-inch wide. After they have been cut off they are ground to the correct thickness, and are then cut with a diagonal cut, as indicated at B, and from 5/32 to 3/16 of an inch of metal is taken off of each.

When one of these rings is closed up so that the edges at B are in contact, it will be found that the ring is slightly elliptical. To counteract this ellipse and to make the ring true once more, it must be turned or ground on the outside. A special arbor of an unusual type is used for this purpose, the construction being practically the same whether it is used for turning or grinding. The arbor, C, is arranged so that it can be dogged at one end and held on centers in an engine lathe or on a cylindrical grinder. A locating flange, D, and a sliding sleeve, E, fit snugly on the portion, C.

The particular type of arbor shown in this illustration is intended to take two packing rings, F.

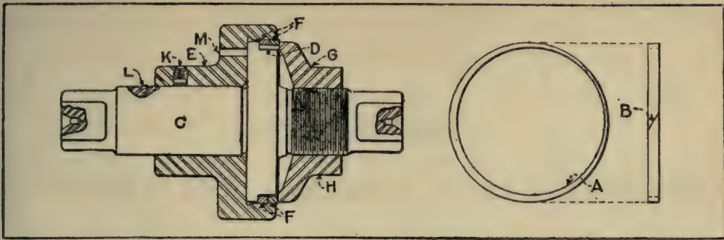


FIG. 89. SPECIAL ARBOR FOR AN ECCENTRIC PACKING RING

These are held firmly against the shoulder by means of the threaded piece, G, which is hexagonal so that a wrench can be used upon it. In using this arbor, the hexagonal nut, H, is removed and the rings, F, are set into the sleeve; the threaded nut is then screwed up upon them until they are firmly held against the shoulders at D. The sliding sleeve is now pulled back out of the way, until the detent pin, K, snaps into the groove, L, which keeps it out of the way of the tool while the work is being done. An air hole is provided at M, in order to relieve the suction and allow the sleeve to be pushed back away from the work without difficulty. Were it not for this provision it would be practically impossible to pull back the sleeve.

Arbors of this kind are in very common use in automobile factories throughout the country. Practically all are made on the same general style, although refinements are sometimes found tending toward more rapid manipulation and quicker handling. However, the type shown is an excellent example of an arbor for work of this character.

CHAPTER XIV

GENERATING AND FORMING ATTACHMENTS

Generating Curved Surfaces.—A cylindrical piece of work may be formed to a prescribed shape by means of a tool itself shaped to the correct contour, or the shape may be generated by a single tool used with a special attachment on an engine lathe, a turret lathe, or a vertical boring mill. If the work to be formed is not cylindrical, a suitable forming attachment can be applied either to a planer, a shaper, or a milling machine in such a way as to produce the desired shape, either with a cutter of special form or with a forming plate that controls the movement of the cutting tool.

Attachments for the planer, shaper, and milling machine are rarely used, except on special work, and as they are highly specialized and the design is generally developed to suit the particular pieces to be machined, it is not necessary to describe them here.

For some very large work, a radial attachment can be applied to a planer and used to generate a curved surface. It is also possible to apply a taper attachment to a planer, but this is not usual as the work can frequently be set at such an angle that the tapered surface to be machined will be in the same plane as the top of the table. Special forms can be

machined on a planer by means of a forming attachment which controls the movement of the tool on the rail. In milling machine work it is seldom that an attachment to produce contours is required. The form of the piece to be milled can be easily generated on a profiler by suitable forming plates. It is entirely possible, however, to generate simple forms on a milling machine by the application of a proper fixture and a suitable forming plate. These several machines are so seldom used for forming that we have only the proposition of forming as applied to the engine lathe, turret lathe, and vertical boring mill to consider. Therefore, as these three machines are most commonly used for work of a cylindrical nature, the attachments described are particularly applicable to this class.

Simple Radius Generating Attachment.—The engine lathe is frequently used either by the application of a forming attachment at the back of the lathe or by some special arrangement applied in a suitable manner. The construction of any such attachment depends somewhat upon the work to be machined. Standard forming attachments applied to the rear of the machine can be obtained from manufacturers of certain engine lathes; but as these attachments are generally designed to operate longitudinally along the work, other arrangements are necessary when it is desired to generate a form on the end of a cylindrical piece.

An example of the latter is shown in Figure 90, where an arrangement for generating a radius on the end of the piston is seen at A. It will be noticed

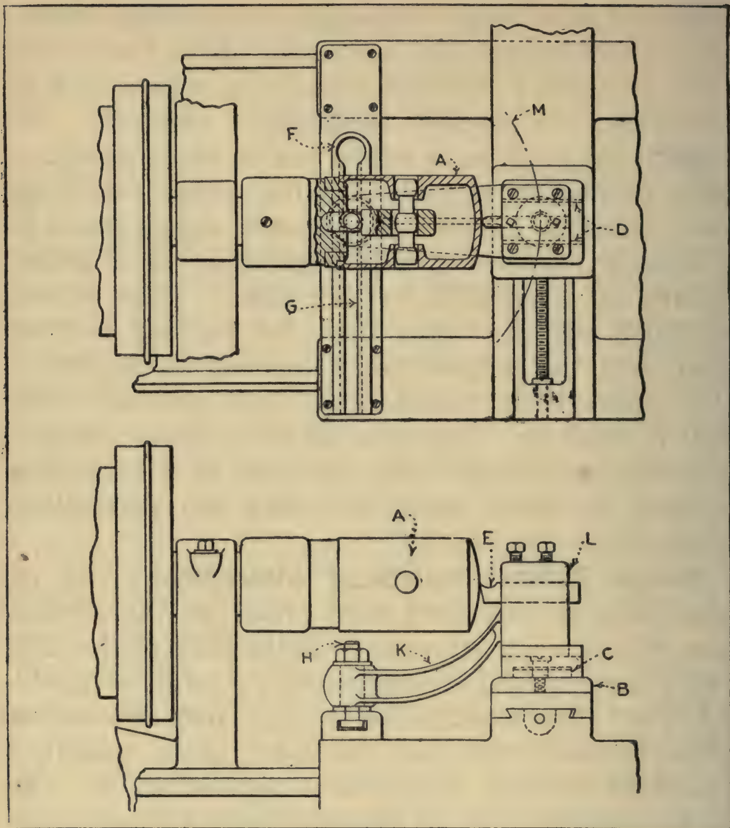


FIG. 90. RADIUS GENERATING ATTACHMENT FOR AN ENGINE LATHE

that the end of the work is formed to a perfect radius, and also that the surface is so large that it could not properly be formed with a single tool. The application of the attachment to the lathe made it possible to generate the radius shown in a short time; furthermore the attachment itself was compar-

atively inexpensive. The design was such that considerable flexibility was possible, both in the length of the radius and in its position with relation to the center of the spindle.

The construction of the attachment is simple; a special block, B, is supplied with a swivel top, C, the upper part of which was dovetailed at D. The tool-block, L, was furnished with a tool, E, for cutting the correct form. A special form of bracket, F, is fastened to the carriage as indicated, and a T-slot, G, is cut in it to provide for transverse adjustment of the pivot, H. The arm, K, swings on this pivot, and is attached to the tool-block, L. Thus it will be seen that as the cross feed of the carriage is operated, the tool, E, will be constrained to follow the path indicated by the dotted line, M; except that it can be moved radially as permitted in the tool-block so as to obtain radii of different lengths, if desired, and also to compensate for re-grinding the tool when it becomes worn.

The attachment shown was designed by me a number of years ago for an automobile plant in Massachusetts, and since that time I have used the same idea in several other cases to good advantage. The principal value of this attachment is that it can be made up so cheaply. In addition, it does the work required of it with practically no attention on the part of the operator, and the results produced give excellent satisfaction.

Radius Forming Attachment for Crowning Pulleys.—The ordinary cast-iron pulley, so largely used in machine work, has a "crown" or radius on the

face to which the belt is applied, the purpose of which is to keep the belt from running off. The metal in the pulley at the point which is crowned is usually thin, and consequently cannot be formed with a wide tool of the proper shape to good advantage. In machining these surfaces it is therefore necessary to generate the form by means of a forming attachment.

In the instance shown in Figure 91, the attachment was so made that two pulleys could be crowned at the same time with the two tools indicated at A in the upper part of the illustration. The work, B, shown in the lower part of the figure, is held on an arbor, C, and driven by means of the driver, D, extending through the face-plate and between the spokes of the pulleys, as indicated. This attachment was applied to an old-style lathe, and the necessary movement was imparted to the tool-block, E, by means of the rod, F, passing completely through to the back of the lathe as shown. A roller, G, made contact with the forming plate, H, and was held in place by means of the spring, K. The bracket, L, was fastened to the back of the lathe carriage and was simply used to form a thrust surface for the spring. It will be seen that as the carriage is traversed longitudinally, the two tools will follow the form indicated at H, thus generating the desired surface.

If an engine lathe is furnished with a forming attachment, work of the character shown in Figure 91 can be more easily handled by the application of a suitable forming plate to the forming slide at

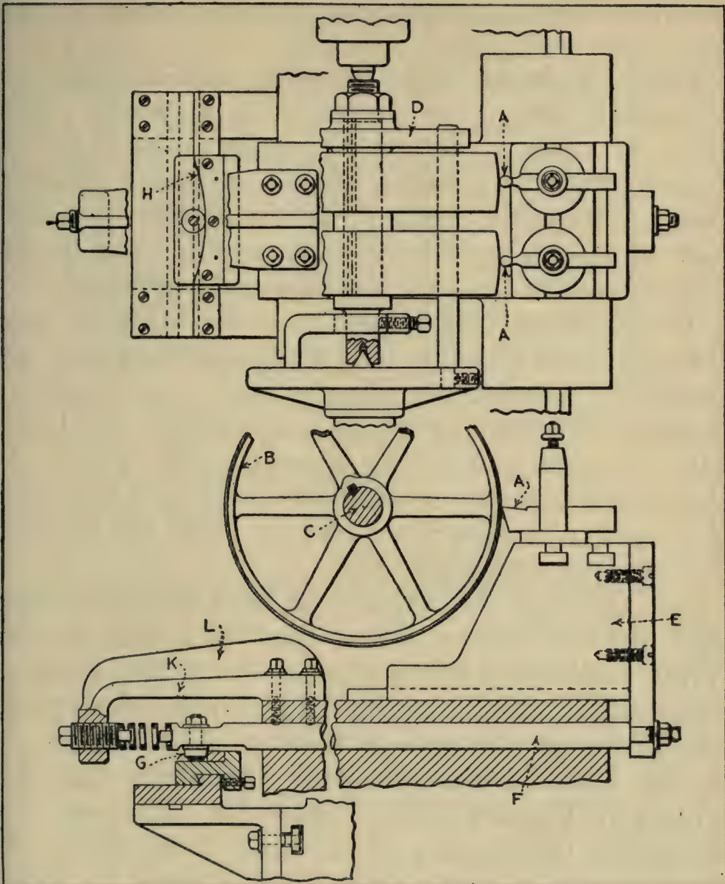


FIG. 91. PLAN AND ELEVATION OF A RADIUS-FORMING ATTACHMENT FOR CROWNING PULLEYS

the rear of the machine. But the general construction of attachments of this kind is similar to the one shown. Many varieties of forms can be generated by means of forming attachments on the engine

lathe; it is only necessary to provide a plate to suit any given case.

Piston Forming and Grooving Attachment.—As automobile pistons are produced in large lots, every effort is made to design the various tools used in the manufacture, so as to provide maximum production. And as the piston of an automobile is a vital part of the motor, the greatest care is used in the manufacture to insure uniformity and accuracy.

Turret lathes are largely used for work of this character, and attachments are frequently applied for combining several operations in one. An excellent example of a forming attachment which is combined with two equipments for grooving the piston, is shown in Figure 92. A plan view looking down upon the machine is shown in order to make the manner of operation more apparent.

The turret of the machine is used simultaneously with the tool shown in the plan view, but as the turret tools have nothing to do with the forming attachment, it would be confusing to show them here. The piston in this case is held on a special chuck, A, this chuck being somewhat similar to that described in Chapter XIII, Figure 86. The work to be done is the forming of the ends of the piston, B, to the required radius, and simultaneously to make the annular grooves, C and D.

In the first place, the cross-slide is furnished with a special block, dovetailed to receive the sliding member which is carried under the block that holds the grooving tool for the surfaces C and D. The dovetailed slide, E, has a roller at F, which is guided

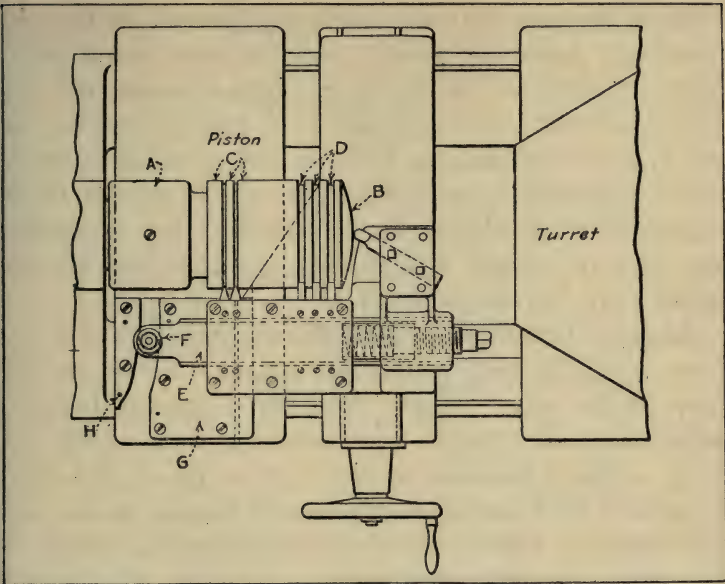


FIG. 92. PISTON FORMING AND GROOVING ATTACHMENT

by the forming plate at G and H, so that the proper form is described on the end of the piston, B. It will be seen that as the cross-slide feed is engaged, the tool for turning the ends of the piston at B travels across the lathe carriage in the path directed by the forming plates. At the same time, the grooving tools are slowly moving forward, until they reach the outside of the piston and begin to cut. At this time the operator changes the feed to a very slow one, so that the grooving tools cut only a little at a time and do not have any tendency to chatter. The feed for a cut of this kind on any kind of a job must be slow, to produce good results, as the cutting action of a grooving tool is not very good.

It is obvious that any such equipment as the one described herewith would only be warranted when high production is desired. Attachments of this kind, however, are applicable to many varieties of work, and combinations of tools can be made to cover many different cases. The number of pieces to be machined must always be considered when designing any sort of special equipment, in order that the expense may be proportional to the production.

Angular Generating Cross-Slide.—For finishing the faces on large ring gears, the angular cut across the face of the gear usually requires a special forming attachment or special equipment of some character. It is entirely possible to machine work of this kind by means of a forming attachment similar to the one indicated in Figure 92, but, of course, it would be necessary to make the forming plates to the correct angle of the bevel on the face of the gear.

A more convenient attachment for either an engine lathe or a turret lathe can be made up, as shown in Figure 93. This is a special swivel cross-slide, and is designed to take the place of the regular cross-slide on the machine, which must be removed to allow the swivel slide to be put in position. The particular advantage of a cross-slide of this character is that it can be swung radially about the center, A, to any angle within its capacity. The ring gear, shown at B in this instance, is to be machined along the face, C. The tool-block, D, on the swivel cross-slide is furnished with two tools, as indicated, for roughing and finishing this angular plate, which are set far enough apart so that the roughing tool

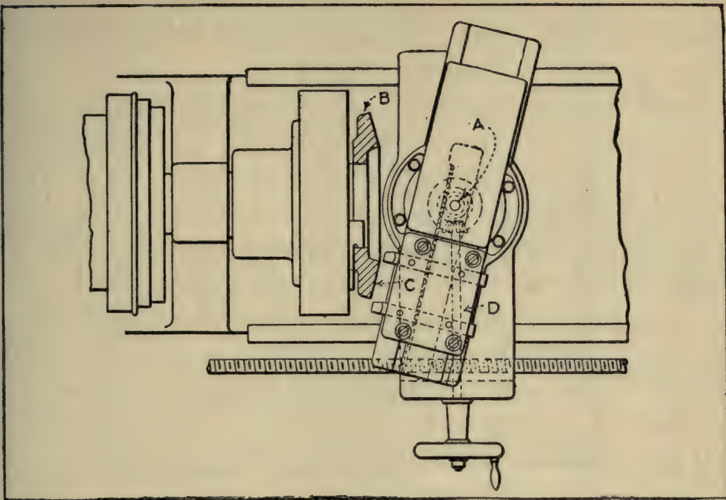


FIG. 93. SPECIAL SWIVEL CROSS-SLIDE FOR A TURRET LATHE

completes its work before the finishing tool starts on the face of the gear.

A swivel cross-slide is not by any means a cheap attachment, but its usefulness and flexibility is such that it can be used advantageously on many kinds of work requiring an angular generating device. Even though the attachment is rather expensive, the construction is simple and it is not likely to get out of order. The feed screw which operates the slide is controlled by a pair of bevel pinions at the center which are always in mesh no matter what the angle of the slide may be. A suitable knock-off can be easily provided to stop the cutting action at any desired point.

Eccentric Turning Device for Packing Rings.—Packing rings for automobile motors are frequently

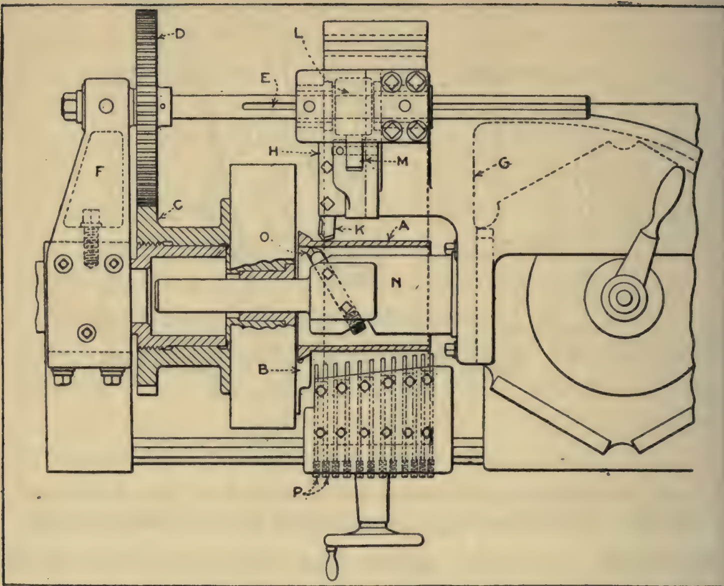


FIG. 94. ECCENTRIC TURNING DEVICE FOR PACKING RINGS

made eccentric, and it is a decided advantage to be able to bore the inside of the ring and turn it eccentric at the same time. For this purpose, several manufacturers of turret lathes have developed equipment to apply to their own product. One such is shown in Figure 94—the eccentric turning and boring attachment for a turret lathe, manufactured and patented by Pratt & Whitney Co.

The work, A, in the drawing, is held by chuck jaws, B, in a three-jawed gear scroll chuck, the faceplate of which forms a ring gear at C, and drives another gear of equal size, D. The latter gear is mounted on a shaft, splined at E, and carried by a

bracket, F, on the spindle cap of the machine. A supplementary bracket, G, is mounted on the turret and carries a slide, H, in which the tool, K, is mounted. This tool is used for turning the outside of the casting, A, eccentric to the inside. The slide, H, is held by the pressure of a stiff spring against a cam, shown at L. As the work revolves, the shaft on which the cam, L, is mounted revolves at exactly the same speed. And as the cam revolves, it bears against a small roller, M, mounted in the slide, so that it moves the tool, K, continually in and out to form an eccentric on the outside of the work. Simultaneously with the turning of the outside of the pot, a boring bar, N, having a tool, O, is used to bore the inside of the ring. Coincident with the action of the boring and turning tool, the tool-block, P, moves transversely, so that the gang of tools mounted on it cut off the packing rings one by one.

This is an excellent example of the application of special attachments to a turret lathe, and indicates the possibilities of this class of machine in manufacturing processes.

Bevel Generating Attachment for a Turret Lathe.— The possibilities of the horizontal turret lathe are little appreciated by the average manufacturer, and it is remarkable how poor a showing some of these high-capacity machines are making in many factories simply because tool designers are not as bold in designs as they might be. For bevel pinions, and other angular work of similar character in which the angle is less than 40 degrees on one side of the center line of the work, a generating attachment for a hori-

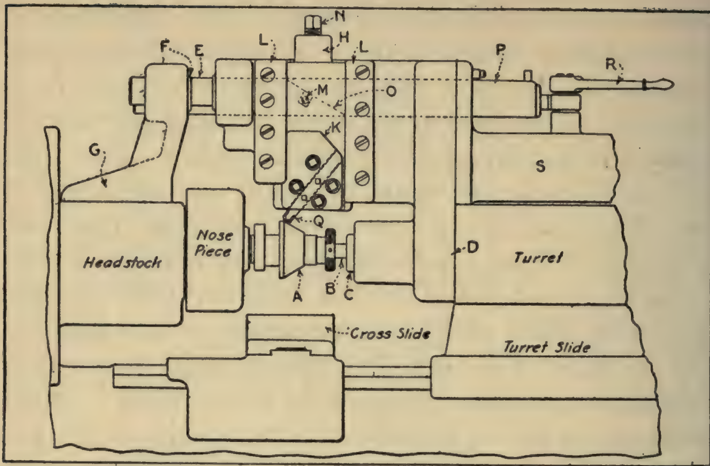


FIG. 95. BEVEL GENERATING ATTACHMENT FOR A TURRET LATHE

zontal turret lathe may be made that will handle a wide variety of work. Such an attachment is shown in Figure 95. The work, A, is held on a special form of arbor where the pilot, B, enters a bushing, C, in the face of the attachment and makes the probability of chatter very remote. The turret of the machine is furnished with a bracket fastened against one of the turret faces, as shown at D. This extends out and overhangs the turret and has a steel pilot, E, at its forward end, which is guided in a bushing, F, supported by the bracket, G. This bracket in turn is fastened to the spindle cap, or to some part of the head construction which is sufficiently massive to permit its being used as a support. This portion of the design depends largely upon the type of turret lathe to which it is to be applied.

The bracket, B, that is fastened to the turret face,

is furnished with a special slide, H, to which tool-blocks, such as that shown at K, can be readily applied. These tool-blocks may have one or more tools in them according to the work for which they are intended. The slide itself is free to move up and down as held by the straps, L. The back of the slide is furnished with a block, M, that is free to swivel. A powerful spring, adjusted by means of the screw shown at M, holds the entire slide up until the swivel block strikes the bevel indicated at O. This bevel is cut on a long rectangular bar of steel, P, properly fitted to a slot in the fixture. The angle of the bevel is made according to the work to be done, but any number of bars may be made up for different bevels, and they can be replaced and substituted one for the other in a moment's time.

The action of this device is extremely satisfactory, and its adaptability is such that it can be applied to a wide variety of work. In operation, the end of the tapered bar (which is guided in the bracket on the headstock) comes against a stop (not shown) before the cutting action of the tool, Q, commences. As the tapered bar does not move after it has been brought to the stop, it is obvious that the entire taper-turning device moves forward along the taper bar, and that the swivel block, M, follows the angle, O, on the tapered bar as it is constrained to do by the swing at the back of the slide. The tool, therefore, follows the same angle, and generates the correct taper on the work.

After the work has been finished, the entire mechanism is withdrawn by a backward movement of the

turret, and any other tools which are on the turret in other positions can be brought into action. After the work has been done on one piece, another one is put in position on the arbor, and the turret is indexed to its original position. After this has been done, the lever, R, is pulled forward to throw the tapered bar ahead into its original position ready for the new job of work.

An equipment of this kind may be made up with two attachments, one of which can be used for roughing and the other for finishing. These two attachments can be on opposite sides of the turret and may be tied together by means of a suitable tie-bracket, such as that shown at S. I have designed several equipments of this kind for bevel gear work and other angular work, and have found them very satisfactory in action.

Radius Generating Attachment for a Vertical Turret Lathe.—The Bullard vertical turret lathe is adaptable in many ways: By the aid of forming attachments almost any kind of shape may be generated, and the machine is of such rigidity that the heaviest cut can be taken with impunity. Incidentally, in regard to the power of the machine, the story is told that upon being asked by a prospective customer, "How many machines can be handled by one man," Mr. Bullard replied, "It takes two men to operate one machine, one to handle the machine and the other to carry away the chips."

The simple attachment for this type of machine, shown in Figure 96, is for forming or generating a radius on the surface of the large pulley, A. The

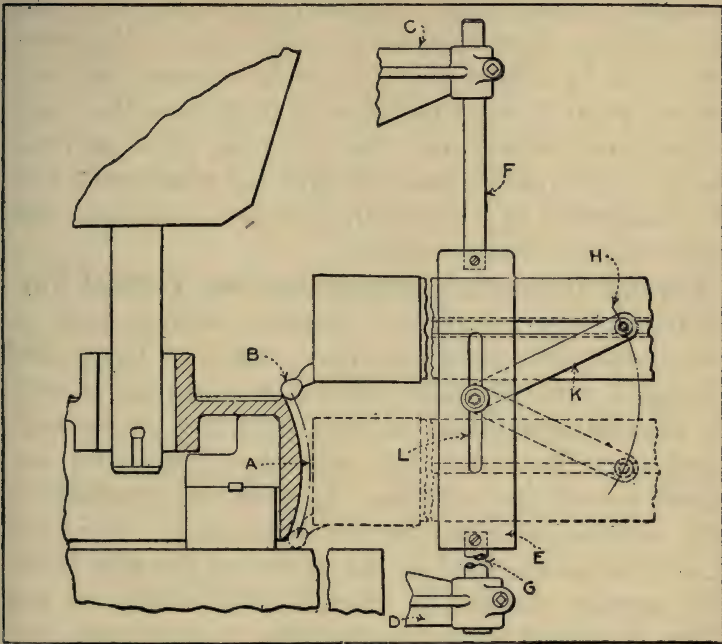


FIG. 96. RADIUS GENERATING ATTACHMENT FOR FACING A PULLEY ON THE BULLARD VERTICAL TURRET LATHE

forming or generating is accomplished by means of the side head with the tool shown at B, and attachments, consisting of a couple of brackets, C and D, are attached to the column of the machine. These brackets support a slotted plate, E, by means of the bars, F and G, which are adjustable vertically. The side head is provided with a T-slot, H, in which a link is pivoted, as shown at K. The radius of the link determines the radius to be generated by the tool at B, and as the link is of the very simplest construction it will be seen that different radii can

be readily established by simply providing an extra link of the desired length. The plate, E, being slotted at L, allows the link to be fastened at any desired point in the slot, so as to determine the exact center from which the radius is to be described. There is little cost connected with the manufacture of an attachment of this kind, and its usefulness and adaptability is quite evident.

Angular Generating Attachment for Vertical Turret Lathe.—To machine an angular surface, such as that shown at A, Figure 97, on work of large size, a Bullard vertical turret lathe may be supplied with an angular generating attachment. Let it be supposed that the bevel ring gear shown is to be machined along the surface, A, with an attachment such as that indicated in the illustration. The tool, B, in this case is held in the turret of the side head, and angular motion is obtained by means of the roller, D, which bears against the angular plate, C. The angular plate is fastened to the side-head ram and is adjustable along the T-slot, X. The roller, D, is also adjustable up or down in the slot shown in the vertical plate, E. Provision for quick removal of the roller is made in the large holes at each end of the slot. The slotted plate is supported in much the same manner as that shown in Figure 96. By means of a forming plate in place of the angular plate, this attachment may be used for forming different shapes if desired, and the entire attachment is sufficiently flexible to handle work with quite wide variations. When the vertical turret lathe is used for heavy manufacturing in quantities, an attachment

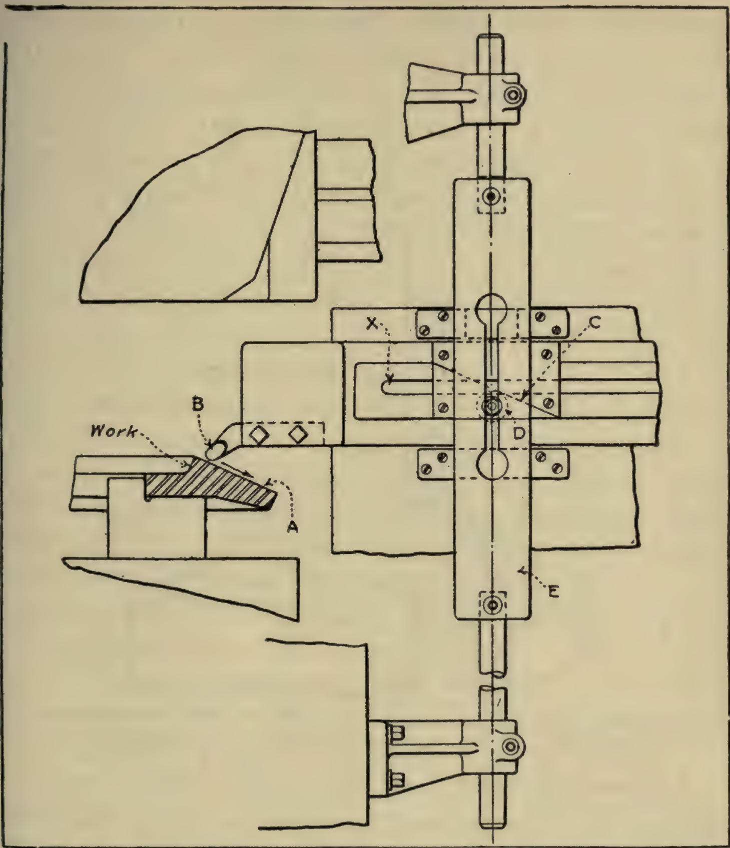


FIG. 97. ANGULAR GENERATING ATTACHMENT

of this kind may be applied with excellent results.

Internal Radius Boring Attachment.—It is occasionally necessary to machine an inside radius on a piece of work, and although conditions requiring such an operation are rather rare, "it is the unexpected that always happens."

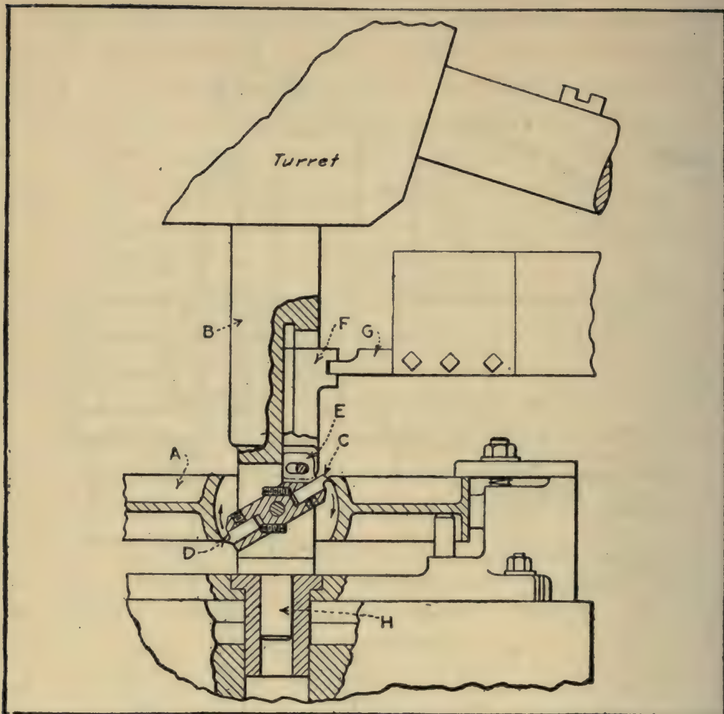


FIG. 98. INTERNAL-RADIUS BORING ATTACHMENT

Let us assume, then, that the work shown, A, Figure 98, is to be machined to the shape indicated, and that the work is to be done on a vertical turret lathe. The attachment shown, made up for the work of the nature indicated several years ago with excellent results, is entirely self-contained in the bar, B. This bar is located in the turret of the machine and is of massive proportions so that it may be rigid enough for the work. The bar is slotted to receive a swiveled toolholder, carrying at each end the tools,

C and D, set to cut the same radius from the center of the bar. A link motion allows the lug at the end, E, to travel radially when it is pushed downward by the sliding block, F, operated by a special rectangular piece, G, in the side-head turret of the machine. It will be seen that when the side-head down-feed is started, the action of the sliding block causes the cutting tools, C and D, to describe an arc, thus generating the inside radius. Rigidity of the bar is assured by the pilot, H, which enters a bushing in the center of the table as indicated.

This attachment is decidedly special, and was constructed for a particular piece of work requiring considerable accuracy. It is not to be supposed that such an equipment will be frequently called for, but conditions may arise in any factory which may necessitate some arrangement for internal radius boring, in which event an equipment of this kind would be of the greatest use.

CHAPTER XV

VERTICAL BORING MILL FIXTURES

Fundamental Construction Features.—Fixtures designed for vertical boring mills are naturally much heavier in construction than those used on a horizontal turret lathe or on the engine lathe. This is perfectly logical, because the work done on a vertical boring mill requires heavier speeds and feeds than the class of work done on the smaller and lighter machines. While a vertical boring mill, or a vertical turret lathe equipped with a side-head, is used for machining many of the same styles of pieces as those handled on a horizontal turret lathe, the difference in the work, however, is one of size; there is comparatively no difference in the method of holding.

One thing, however, must be mentioned in connection with work on the vertical boring mill. That is that the work is revolved in a horizontal plane, and it is not necessary, therefore, to counterbalance any fixture made for an odd-shaped piece, as it would be if the work were to be done on a horizontal machine, where the work revolves in a vertical plane. That is to say, the work spindle on a vertical boring mill has the center line or axis of rotation in a vertical plane, and the work revolves horizontally;

while on the horizontal turret lathe the center line or axis of rotation is in a horizontal plane, and the work revolves vertically.

In vertical boring mill practice, therefore, the work may be laid down on the table of the machine and can readily be clamped down to it. The weight of the piece really assists in holding it; and the only thing necessary in the clamping device is that pressure enough be applied to keep the work from slipping under the pressure of the cut. It must also be remembered that the cuts taken on these heavy boring mills, are greatly in excess of those used on horizontal machines.

For many kinds of heavy manufacturing work the vertical boring mill or vertical turret lathe can be used to great advantage, and the massive construction of these machines permits work to be done within close limits of accuracy. Furthermore, machines of this type can be easily set up with a comparatively small outlay for tool equipment, so that although the first cost of the machines is rather large, the productive efficiency is extremely high.

Vertical Boring Mill Fixture for Thin Work.— The problem of holding and machining a piece of thin work is always more or less difficult, because it is not easy to hold the work without distorting it, and in addition, the work is likely to be sprung out of shape by the pressure of the cut in machining. It is necessary, therefore, in designing a method for holding a piece of thin work, to strive to prevent both distortion from the holding device and distortion from the pressure of the cutting tool.

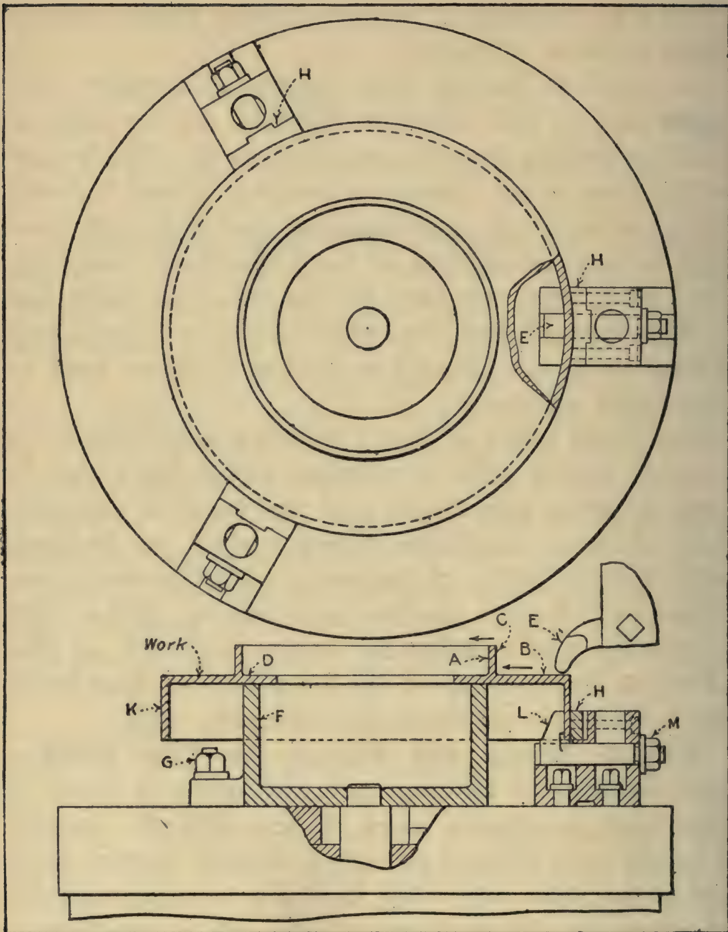


FIG. 99. METHOD OF HOLDING THIN WORK ON A VERTICAL BORING MILL

An excellent example of a piece of work of thin section to be machined on the vertical boring mill is shown in Figure 99. The method used for holding this piece and supporting it while machining, can be applied to a number of cases of similar character with slight variations. The work is large in diameter, and it is necessary to machine it on the surfaces A, B, C, and D. Since the web, B, is very thin, it is necessary to support this portion of the work to keep it from swinging downward while the cutting tool is in action. The direction of the cut is indicated by the arrows; and the tool which is used on the portions B and C, is shown at E in the side-head of the machine. The work is laid down upon a special cast-iron locating ring, F, which is held down by lugs, indicated at G, in the table key-slots. The work is centered by means of the special hook-bolt jaws, H, which are soft and bored out to fit the outside of the work. (Incidentally, the work has been finished on the surface, K, in a previous setting.) The three jaws indicated are attached to the master jaws on the table chuck, as shown in the upper view, and, as the table chuck is of the three-jawed geared scroll variety, the work is readily centered on the table. The jaws are brought up very lightly on the outside of the work, so as not to cause any distortion; and after they are brought in contact with the work, the hook bolts, L, are tightened by means of the nut, M, so that the work is gripped at three points around the circumference in much the same manner as though it were held in three separate vises. It can be easily seen that this method

of holding is exceptionally rigid and does not cause distortion in the work. The pot, F, acts as a locating device to give the correct height to the work, and at the same time it supports it against the pressure of the cut.

Special Fixture with Tapered Plug Locater.—It is frequently necessary to locate a piece of work on a tapered hole that has previously been machined, and at the same time to hold the piece by means of clamps on some other portion. As it is a difficult matter to machine a tapered surface and a plane surface so that they will always bear an exact relation to each other, some method of holding must be used which will compensate for the variations between the two surfaces.

Let us take as an example of this kind of work the piece shown at A, Figure 100. This work is a flywheel for an automobile engine, and it has been machined in a previous setting in the tapered hole, B, and also on surfaces C, D, and E. Now in order to machine the side of the work, F, and the hub, G, so that they will be in the correct relation to the previously machined tapered hole, it is necessary to locate the work on a plug in this tapered hole. But while this location would be all right, it would not be possible to clamp the work easily without springing it out of shape if it were to be located only on the tapered plug. The surface, D, then, must be used for attaching an additional clamp, but as this surface may vary slightly in its relation to the tapered hole, any method of clamping must be so designed that compensation may be made for sur-

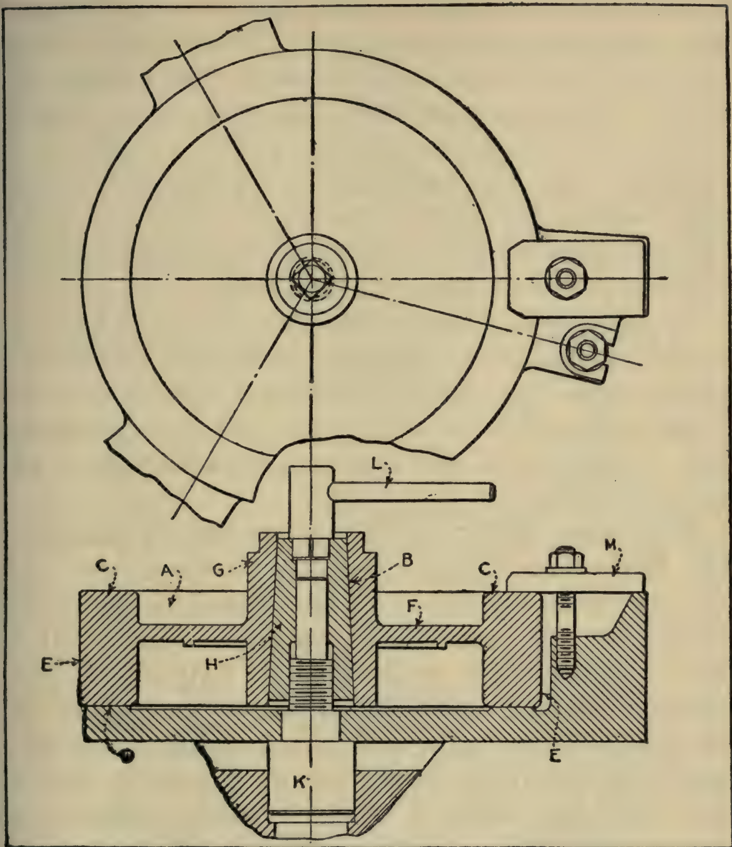


FIG. 100. HOLDING A PIECE OF WORK BY ITS TAPERED HOLE

face variations. This is accomplished by making a tapered plug or shell, as shown at H, and locating this shell on a threaded stud, K, set in the center hole in the table. The upper end of the tapered shell is squared out to receive the special socket wrench, L, by means of which it is operated.

The method of using this fixture is as follows: The plug is lowered by means of the screw, so that the work can slip onto it loosely. The clamps, M, which are three in number, are then set up lightly on the rim, C. After this, the socket wrench, L, is used to screw the tapered bushing up in the hole, thus locating the work on the tapered portion. After this has been done the clamps are tightened securely, and the work is ready for machining.

Applications of this principle can often be used to hold work of this character, with various methods of compensating. The tapered shell bushing is sometimes arranged on a spring, so that it is self-locating. A method of this kind is quite satisfactory and generally gives good results.

Expanding Arbor and Faceplate for Vertical Boring Mill.—For a piece of work that has been previously machined and is to be located in the second setting by the previously machined surface, it is necessary to make up a locating fixture. A good example of such a fixture is shown in Figure 101. In this case the work, which is a double bevel gear, has been previously machined at A and B, and on the bevel-gear faces, C and D. It is necessary to locate it for this operation by means of the hole, B, and, as the work must be very accurately done, an expanding arbor must be used in the hole. In conjunction with the expanding arbor, it is necessary to prevent the work from springing at the surfaces of the outer bevel-gear ring, D.

A cast-iron fixture body, E, is located in the center of the table by means of the plug, F, which enters

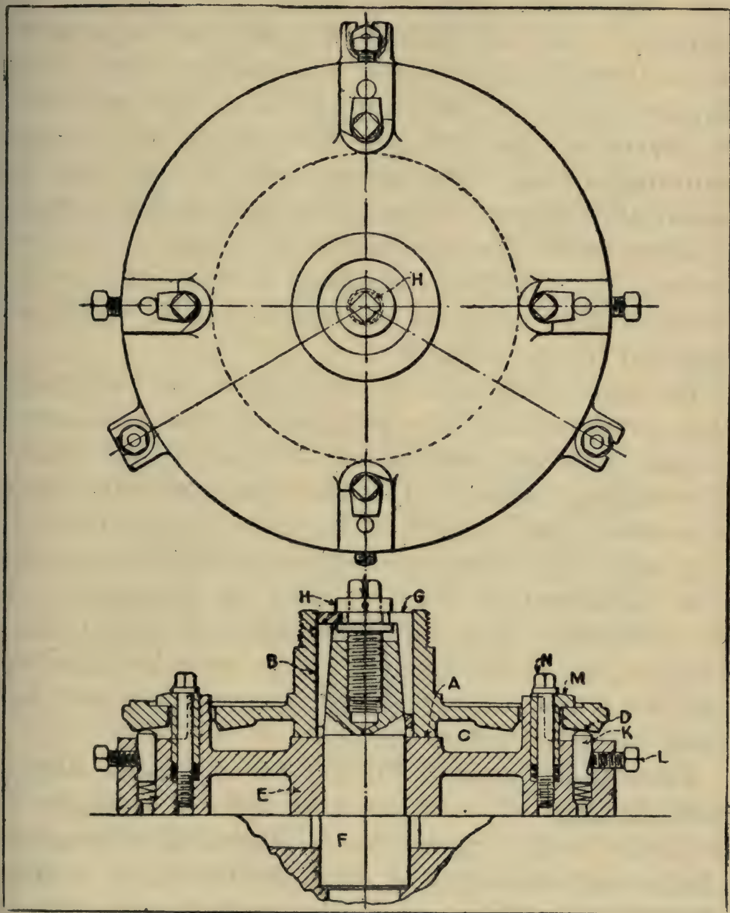


FIG. 101. PLAN AND SECTION OF EXPANDING ARBOR AND FACE PLATE FOR VERTICAL BORING MILL

the center hole. The work is placed in position over the central plug and drops down against the surface, A, of the fixture. A split ring, G, similar to the type described under the heading "Split Ring Expanding Arbor," Chapter XIII, is then expanded by means of the bolt, H, thus giving the desired centering action. The spring jacks, K, are now released and allowed to spring up against the surface, D, after which they are locked by means of the set-screws, L. The final clamping of the work is accomplished by means of the hook-bolts, M, which are operated by the bolts, N.

The principle shown in this fixture can be applied to a great variety of work, and it can be adapted to suit different conditions, both as to the means of clamping and as to the points on which the work is located. Any method of clamping applied to a fixture which has been previously machined must take into consideration the fact that no distortion can be permitted. The use of springs and spring jacks for this purpose is common. Care must be exercised that when the set-screws are tightened they will not force the jacks out of position.

Vertical Boring-Mill Fixture for a Fragile Aluminum Casting.—One of the most difficult examples of a fixture for holding a piece of thin work of irregular shape, and machining it when held without causing distortion in the work, is shown in Figure 102, at A. In the plan above it will be seen that the casting has a thin flange of approximately elliptical shape and the face of this flange is to be machined in the setting indicated. In addition to this the face,

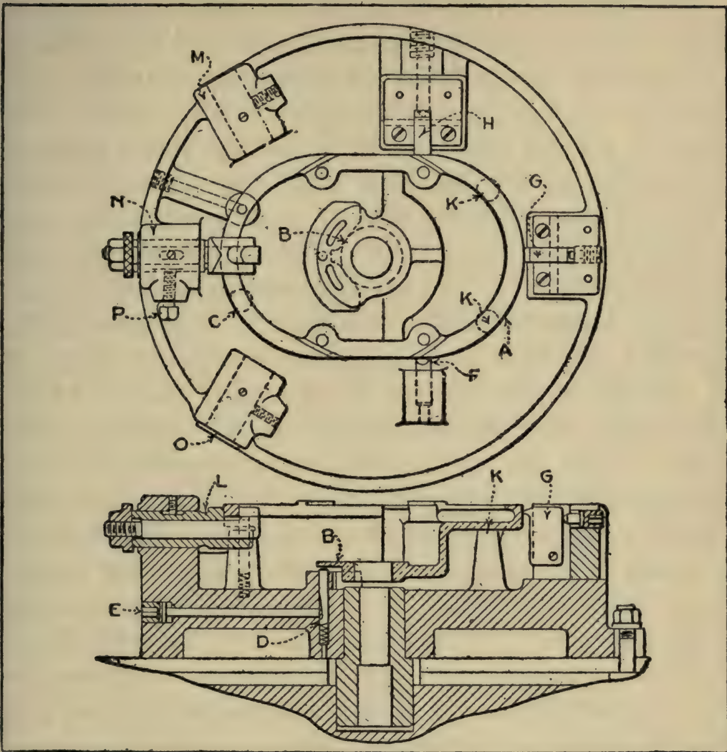


FIG. 102. PLAN AND SECTION OF A VERTICAL BORING MILL FIXTURE FOR A FRAGILE ALUMINUM CASTING

B, located below the surface of the other flange, must also be faced in the same operation. The part of the flange indicated at A is joined to the right-hand portion of the casting, as indicated in the sectional view below. The other side of the flange, however, at C, is open and unsupported, making it very difficult to hold the piece without forcing the parts out of alignment.

This piece of work is one of the most difficult that I have ever encountered, and I give it here simply to show the possibilities of arranging clamping devices so that they will not distort the work. The piece is set up with the boss, on the under side of B, locating in a V-block on the fixture base, and the edge of the adjacent flange is supported by the spring pins indicated at D. These spring pins are locked by means of the special screw, E. The flange, A, rests against a knife-edge locater, F, and is lightly clamped by means of swinging knife-edge dogs at G and H, while resting on the pads shown at K. The other side of the flange, C, is simply a rim which must be held and firmly located without springing it out of position in the slightest degree. For this purpose, the floating hook-bolt, shown at L, is made in triplicate. These bolts are used in the three bosses, M, N, and O, although only one of them is shown in the illustration. The action of the hook-bolts is such that the work is clamped between the jaws shown while the entire mechanism "floats", so that it does not strain the work. After the hook-bolt is tightened, it is locked in place by means of the set-screw, P.

By this method of clamping, any piece of delicate section may be clamped without causing distortion. Although the example shown is a rare case, the principles involved in this design can be applied with equal success to other work of similar nature. It is sufficient to say in regard to the fixture mentioned that its work was in every way satisfactory and the work was machined without error.

Simple Fixture for Machining an Eccentric.—An example of a fixture for turning an eccentric piece was shown in the group of fixtures in Chapter XII, but in that case the work was held on a swinging fixture applied to a horizontal turret lathe. Another example of an eccentric turning fixture of the indexing type, but arranged for a vertical boring mill, is shown in Figure 103. In this case, the work is set up on an indexing plate, A, by means of the three pins, B, in the flange. This indexing plate is located eccentrically on a base, C, which is fastened to the boring mill table, being located on a plug, D, in the center hole. After the work is set up on the pins, it is clamped in place by means of the three hook-bolts shown at E, these bolts being brought down on the flange as indicated in the upper view. When clamped in the position shown, the hole, F, is bored, and then the upper part of the fixture, A, is swung around until the center, G, takes the place of the hole previously machined. A locating pin is provided at H to give the correct location.

In indexing the fixture, the button clamps around the rim, as shown at K, and is loosened to permit the revolution of the portion, A; but when the table has been indexed to the proper position these clamps are again tightened before the machining takes place. The next operation on the work is the machining of the eccentric, L, when it has been indexed into the position mentioned. After this the work can be removed from the fixture and another substituted for it.

Work of this character is frequently machined in

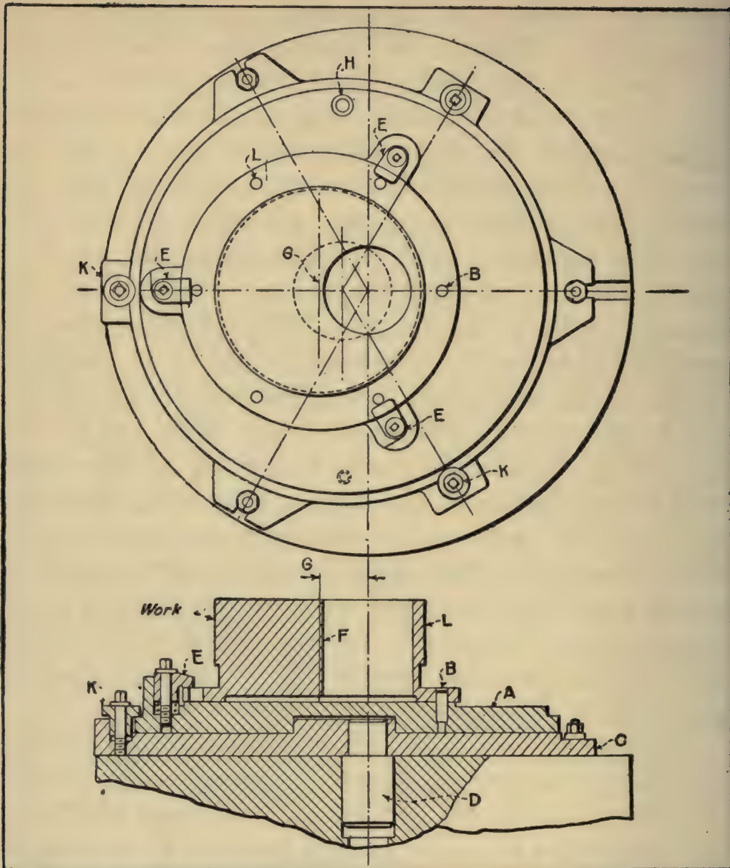


FIG. 103. PLAN AND SECTION OF A FIXTURE FOR AN ECCENTRIC PIECE OF WORK

two settings, and no attempt is made to make an indexing fixture such as that shown. In such an event the ordinary method of procedure is to bore the hole first and then locate the work on another fixture on a stud set eccentrically to the center for

the turning of the eccentric surface, L. The matter of designing a fixture for a piece of work of this kind is dependent entirely upon the number of pieces to be machined and the accuracy required in the finished product. Application of this principle may be made to many varieties of work where two surfaces are machined eccentric to each other.

Sliding Fixture for Boring a Pair of Cylinders.—When a pair of cylinders, such as those shown in Figure 104, at A and B, are to be bored and faced on a vertical boring mill, the work must be handled either by means of two settings, or by an eccentric or sliding fixture. If two settings are to be used, the ordinary method of handling is to machine one of the cylinders first and then set it up on a stud eccentric to the center of the table at the correct distance to bring the center of the second cylinder into position for boring. For rapid production, however, a sliding fixture or one having an eccentric movement can be designed, so that the work can all be handled at one setting, thus saving considerable time in the machining and in the handling of the work.

The device shown in Figure 104 consists of a base plate, C, which is fastened to the table and is centrally located by means of the plug, D. The base plate is held by means of the bolt, E, in the table T-slot as indicated. Mounted on the base plate, C, is a dovetailed slide, F, on which suitable clamps, G, are provided to hold the work. A sectional view taken through the base is shown at H. Along each side of the sliding members are two handles, K, for

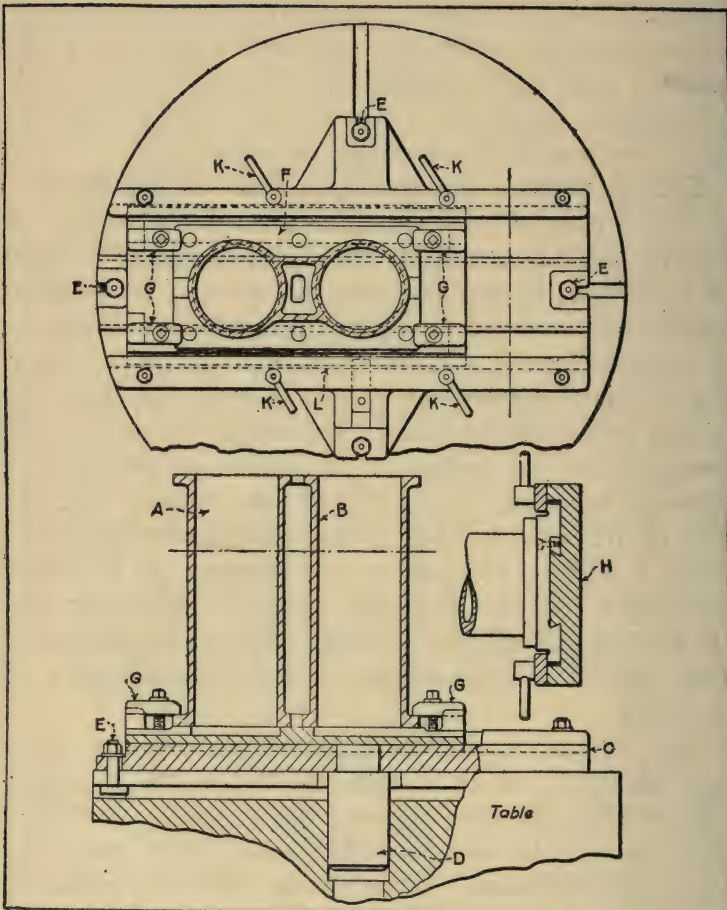


FIG. 104. SLIDING FIXTURE FOR BORING A PAIR OF CYLINDERS

the purpose of locking the sliding fixtures in any desired position. After one of the holes has been bored, the handles are unscrewed and the fixture is pushed over until the second cylinder is under the center of the spindle, the correct location being assured by means of a taper pin, L. When the desired position has been reached, the levers, K, are again tightened, and the second cylinder may be bored in exactly the same manner as the first.

Threaded Knock-off Arbor for Vertical Boring Mill.—The work shown at A, Figure 105, is a large head used for a rock drill. The piece is made of chrome-nickel steel which is extremely hard to cut. The work has been previously machined on the inside surfaces, B, and has been threaded at C as indicated. It is necessary to machine the outside tapered surfaces, A and B, in another setting, and these surfaces must be in correct relationship to that previously threaded inside of the work. A knock-off arbor was therefore suggested, such as that indicated in the illustration.

This work was to be done on a vertical boring mill, and accuracy was an essential point. The base of the fixture, D, is located on the table of the machine and is held in place by means of the bolts, E, which pass through the T-slot in the table and are clamped by means of the shoes shown at F. The location of the plate is obtained by means of the threaded stud which is ground to a fit at G in the central hole of the table. The right-hand threaded arbor, H, is made at the upper part, so that the thread corresponds to the inside thread in the work at C. Below

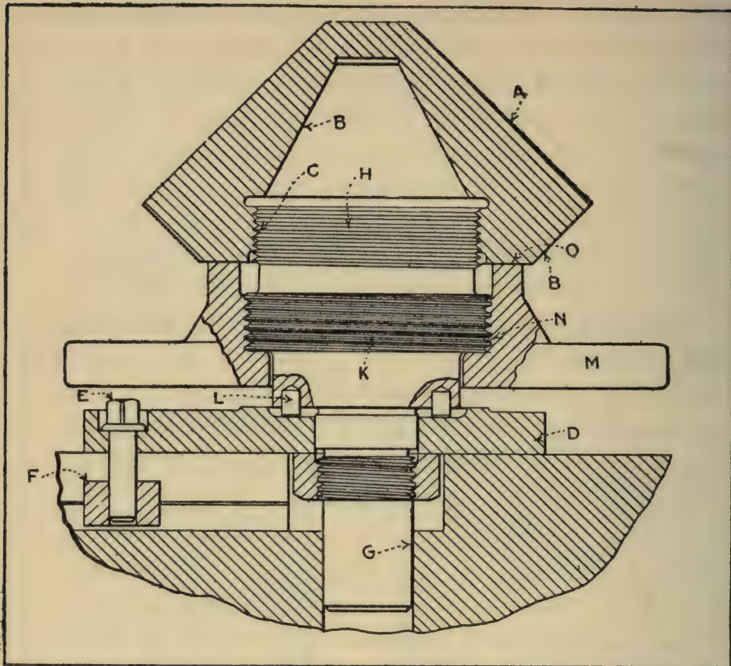


FIG. 105. THREADED KNOCK-OFF ARBOR FOR A VERTICAL BORING MILL

this a left-hand thread is cut at K. The lower part of the arbor is provided with two pins, L, in order to give good driving properties. The knock-off portion of the arbor is shown at M, with a left-hand thread to fit the part K.

Let it be supposed that the fixture is about to be loaded by attaching the piece A. At this time the knock-off portion, M, is screwed up until it shoulders against the portions N. The work, A, is then screwed on until it makes up against the surface O. The

work is now ready for machining, and during the action, because of the pressure of the cut, the surface, O, becomes very tightly in contact with the knock-off pad. After the work has been done, a sharp blow on one of the projecting lugs of the knock-off, M, causes the pressure at the point O to be relieved, so that the work can be easily unscrewed from the arbor. The principles involved in this arbor are practically the same as those described in Chapter XIII, under the heading "Expanding Arbor for an Adjusting Nut."

CHAPTER XVI

GRINDING FIXTURES

Adaptability of Cutting Fixtures.—The functions of grinding as practiced by manufacturers in general have been taken up in Chapter VII, but the matter of holding fixtures for the grinding operations has not been dealt with to any extent. As a matter of fact, fixtures used for grinding purposes are very similar to those used in various machining operations, although the necessity for holding the piece rigidly is not present, since the amount of pressure exerted on the work by the grinding operations is nothing like as severe as by the cutting operations. Many of the fixtures devised for machining operations can be used for grinding, but as a rule grinding fixtures are considerably lighter in construction than those used for turning and facing.

The principles which apply to holding devices of various kinds for turning can be applied to grinding practice, with proper modifications to suit the conditions. For example, there are many cases where a spring clamp can be used for a grinding fixture with excellent results, and yet such clamps would not be suitable in any way for machining operations on account of their lack of holding power. The pulling action of a grinding wheel taking a very light

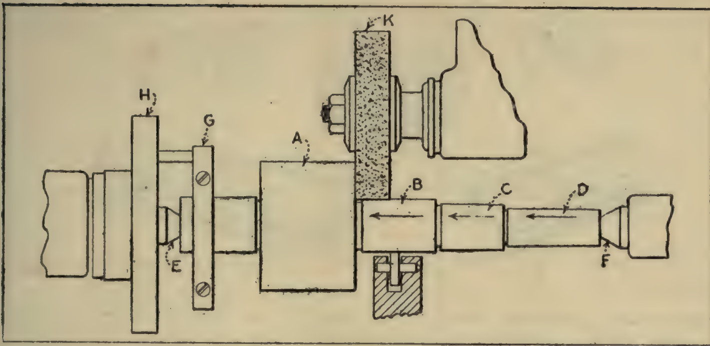


FIG. 106. METHOD OF SETTING UP A GRINDING MACHINE FOR EXTERNAL CYLINDRICAL GRINDING

cut is nowhere near as severe as when a cutting tool is used on the work.

When cylindrical work is to be ground, there is seldom a need for any sort of grinding fixtures—unless some portion of the work is irregular, in which case a special method must be used for holding. The ordinary method of locating and holding a piece of cylindrical work for external grinding is illustrated in Figure 106. The work, A, in this case has several shoulders, B, C, and D, which are to be ground in the setting indicated. The work is located on the centers shown at E and F, and is driven by a dog, G. which enters the driven faceplate, H. While the work is in the position indicated, the wheel, K, is traversed in the direction indicated by the arrows until the various diameters have been ground to the correct size. It will be seen that no special equipment of any kind is necessary in performing work of this character.

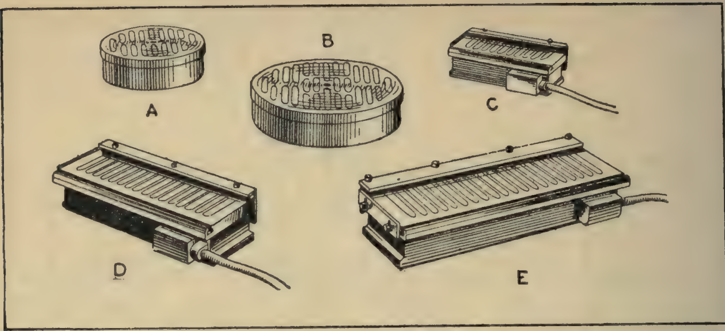


FIG. 107. ROTARY AND RECTANGULAR MAGNETIC CHUCKS

Magnetic Chucks.—Frequently, however, cylindrical work requires special fixtures, for although the portion which is to be ground may be cylindrical, it may happen that the method of holding must be special in order to accommodate a peculiarly shaped piece. Chucks, either magnetic or the step-chuck type, are largely used for holding work which is to be ground. When the work permits the holding by magnetic chucks, this method is largely used and gives very satisfactory results. Otherwise, a step-chuck can be arranged to handle the work.

A group of magnetic chucks, made by the Heald Machine Co., is shown in Figure 107. Those shown at A and B are of the rotary type, while those shown at C, D, and E, are of the rectangular type, not used on rotary machines, but applied principally to surface grinding. One of the great advantages derived from the use of magnetic chucks is the rapidity with which the work is applied to and removed from the chuck. Another advantage lies in the fact that there is little danger of distortion caused by an im-

proper method of clamping. This feature is particularly noticeable when thin work is to be ground. Still another advantage is that a great number of pieces can be held at the same time. It is only necessary to throw a switch in order to apply the electric current, magnetize the soft iron core of the chuck, and hold rigidly any work on its surface.

The rotary chuck, shown at A and B, can be applied to a horizontal machine for cylindrical grinding, or to a rotary surface-grinding machine. Piston rings or packing rings, for example, are usually ground on their edges on this type of chuck. The rectangular type of chuck, shown at C, D, and E, is particularly suited to surface grinding and to milling or planing operations. In application they hold a number of small pieces or a single piece of long work.

Many uses will be found for these chucks in a manufacturing establishment, and the type of chuck most suited to any man's work can best be determined by consultation with the various manufacturers. Suitable demagnetizers are applied to all chucks of the magnetic type, so that after the work has been removed, no future trouble is experienced from magnetism remaining in the work.

Grinding Fixture for Universal-Joint Part.—A number of pieces in an automobile are made of alloy steel that requires special methods of hardening. One of these pieces is the rocker arm of the universal joint, shown in Figure 108 at A. This piece must be ground on the two cylindrical portions B and C, and it requires a special fixture as indicated at D. This

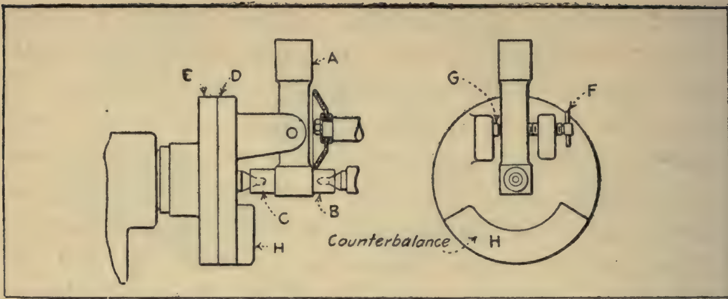


FIG. 108. FIXTURE FOR GRINDING UNIVERSAL JOINTS

fixture is not designed for the purpose of holding the work, but merely to provide a means for driving the long end, A, and preventing vibration of the work during the process of grinding. Such a fixture as this can be mounted on an adapter plate, as at E, attached to the spindle of the machine and rotated.

The work in Figure 108 is held on the faceplate, and is located on two centers, as indicated. A suitable thumb screw is provided at F on the fixture, so that when the work is placed in position the thumb screw can be tightened to throw the work over until it strikes a stud, G. Since this fixture with the work in position is heavier on one side than on the other, a cast-iron lug, H, is applied to the opposite side, as shown, so that the entire fixture can be properly balanced before the work is done. If a grinding fixture of this sort were to be made up and not properly balanced, the action on the entire machine would be injurious and the work produced would not be true. It is not only advisable but necessary to see that any fixture used for grinding is properly balanced to obtain the best possible results.

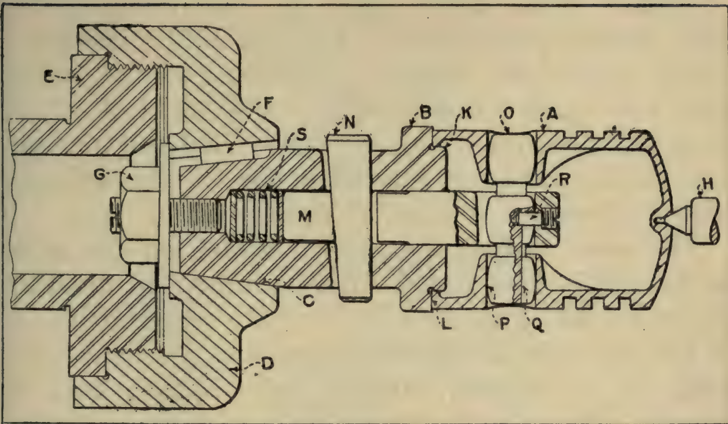


FIG. 109. FIXTURE FOR GRINDING PISTONS

Piston Grinding Fixtures.—Manufacturing practice differs in regard to the finishing of automobile engine pistons, but most makers finish the external surface of the piston by grinding. When this is done, accuracy can be more readily kept within the required limits, and the superior finish gained by the grinding is an added advantage.

A fixture for holding an automobile piston while grinding is shown in Figure 109. In this case, the work, A, is located on an arbor, B, which is drawn back into a tapered hole, C, in a special nose piece, D, which is screwed to the end of the last spindle, E. A key to hold the work on the spindle is provided at F, somewhat unnecessarily in the instance shown. I say unnecessarily, because the amount of friction generated by the grinding wheel against the outside of the piston, A, could never be sufficient to permit the arbor, B, to turn in the tapered hole,

especially when drawn back by means of the nut and washer shown at G. The end of the piston is given additional support by means of the center shown at H, this center being in the tailstock of the grinding machine. The method of holding the piston on the arbor is somewhat out of the ordinary and is therefore worthy of description.

The open end of the piston locates on the arbor at K, and is drawn back firmly against the shoulder, L, by means of the rod, M, and the taper wedge, N. When the work is placed in position, the ball-ended plug, O, is dropped through the wrist-pin hole, P, passing through the draw-back rod as indicated. After this has been done the wedge, N, is pushed lightly into place until the operating rod, M, draws back on the pin, O, to carry the work up against the shoulder, L, where it is held firmly. A slot is cut in the pin, O, as indicated at Q, so that the retaining pin, R, will prevent it from falling out of the work. The purpose of the spring indicated at S, is to force out the rod, M, after the work has been done and when the wedge, N, is pushed back. A grinding fixture of this sort can be applied to many varieties of work with suitable adaptations to conform to the style of work to be gound.

Internal Grinding Fixtures—A Ball-Bearing Cage. —Let it be assumed that the work A, Figure 110, has been previously machined at all necessary points, has subsequently been hardened, and that it is now necessary to grind the hole, B, in correct relation to the cylindrical surface, C. In actual operation, the hole, B, is ground to size first, and the work is then placed

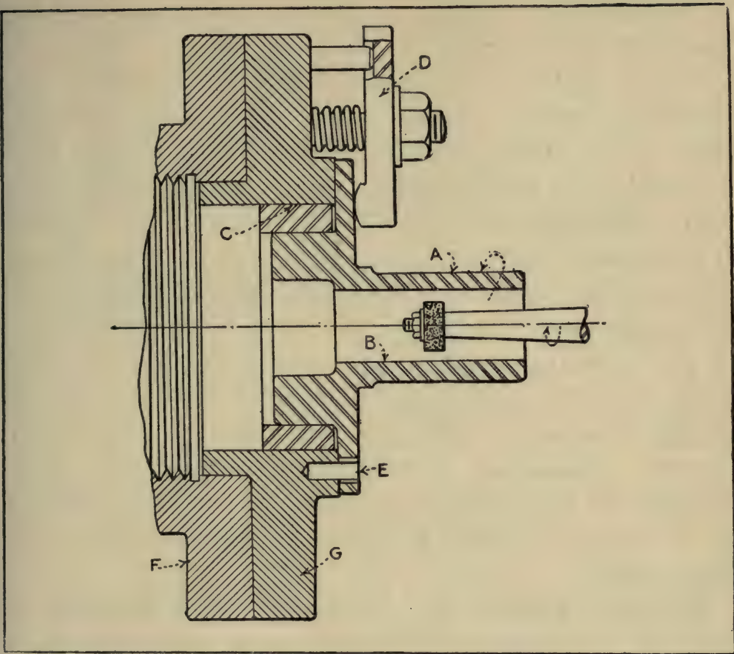


FIG. 110. FIXTURE FOR INTERNAL GRINDING A BALL-BEARING CAGE

on an expanding arbor and the surface, C, is ground in the correct relation to the hole, B. The fixture used for grinding the hole, B, was originally made up for boring and turning, but was later adapted to the present use. Since the fixture was made up for a heavier variety of work than a grinding operation, the clamps shown at D are much more suited to a turning operation than they are to a grinding fixture; so, also, the driving pin shown at E would usually be considered unnecessary if the fixture were made up for a grinding fixture. This example is given principally to show how a fixture made up

for turning and boring can be adapted to a grinding operation if necessary.

If this fixture had been designed originally for grinding, spring clamps could have been used in place of the straps shown at D, and the driving pin, E, could have been omitted. In addition to this, the entire fixture could have been made much lighter in its general construction, and would have answered the purpose fully as well. The adapting plate, F, was made up in this particular case to fit the spindle of the grinding machine, and the faceplate, G, was fitted to it as indicated. A special form of chuck, having a series of jaws and operated by means of a draw-in mechanism through the spindle, can often be used for work similar to that shown. An example of this type of holding device is described later in this chapter.

Grinding Fixture for Universal Joint Member.— A good example of a fixture used for grinding a tapered hole is shown in Figure 111. This fixture has a number of commendable points, one of which is that it may be adjusted to take care of slight variations caused by distortion in hardening the work previous to the grinding operation.

The method of setting up the work in this instance is rather out of the ordinary. In the first place the work requires that the tapered hole, A, must be ground concentric with the hole, B, and at right angles to the cross-hole, C. For this reason the work is located on a sliding rod, D, which has a bearing in the spindle at E, so as to run concentric with the spindle. A shoulder, B, on the rod, D, locates the

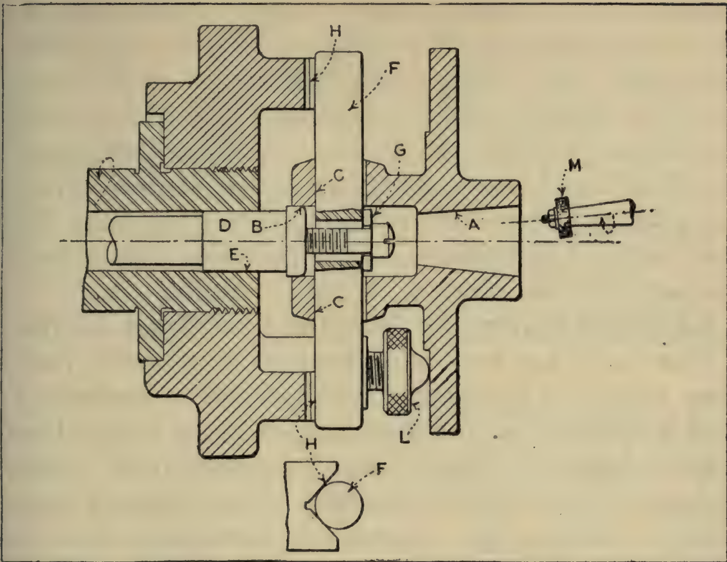


FIG. 111. GRINDING FIXTURE FOR A UNIVERSAL JOINT MEMBER

work in a central position. After it is so located, the hardened and ground bar, F, is passed through the cross-hole, C, after which the washer, G, is slipped into place and the draw-back rod, D, operated from the rear end of the spindle, pulls back the work until the bar, F, seats itself in the two V-blocks, H, on the fixture. (The small detail shown below the illustration indicates the method by which the bar, F, is located in the V-block.)

A refinement provided on this fixture is the knurled button, L, whereby variations in the work can be compensated. There are three of these buttons located 120 degrees apart on the face of the fixture, but only one of them is shown in the illus-

tration. An indicator may be used in the hole, A, to approximate its truth before the grinding takes place, and these buttons can then be set up to bring the hole in the desired position. After the work has been properly set, it is ground by the small grinding wheel shown at M, using an internal grinding attachment or an internal grinding machine for the work. Applications of the principle shown may be used for other cases of similar character.

Adaptable Fixture for Grinding Spur Gears.—After a spur gear has been machined and the teeth have been cut, it is frequently put through a process of pack-hardening or treating in some way to produce a hard and, at the same time, a tough texture to the metal, so that it will withstand abuse without fracturing. During the process of hardening there is likely to be a slight change in the shape of the work, and as it is essential that a gear should have its teeth cut in correct relation to the center hole, a method of compensating for any error from the hardening process is highly desirable.

The work, A, shown in Figure 112, is a spur gear which has been hardened and in which it is desirable to grind the hole, B, which will be concentric with the teeth around the periphery of the gear. To assure this result the method of locating the gear must be determined either by the pitch line of the teeth or else from the bottom of the teeth, for there is little likelihood that these points will change their relation to the center of the gear because of distortion in hardening. For a spur gear the bottom of the tooth is usually selected as the locating point.

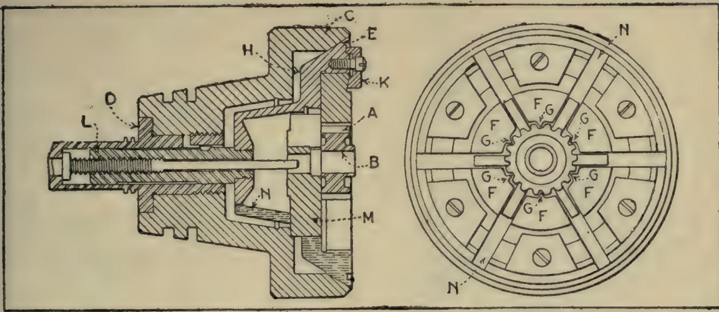


FIG. 112. SECTION AND PLAN OF AN ADAPTABLE FIXTURE FOR GRINDING SPUR GEARS

The fixture shown in the illustration consists of a nose piece, C, mounted on the spindle, D, and provided with a tapered portion, E, as indicated. The gear is held and located by a series of blocks, F, each of which has a point, G, so designed that it will strike the bottom of six teeth, as indicated. These six blocks are radially located in a split member, H, by means of the clamps shown at K. This split member, H, is slotted in six places in order to allow it to contract as it is pulled back into the tapered portion, E, by means of an internal mechanism running through the spindle as indicated at L. A spider-shaped piece, M, is set into the base piece, C, between the slots, N, which provide for expansion and contraction of the piece, H. This spider is provided in order to give an endwise location to the work.

It will be seen that as the work is placed in the chuck, the points, G, are drawn in radially until they center the work from the bottom of the six teeth as indicated. This mechanism may be applied to a

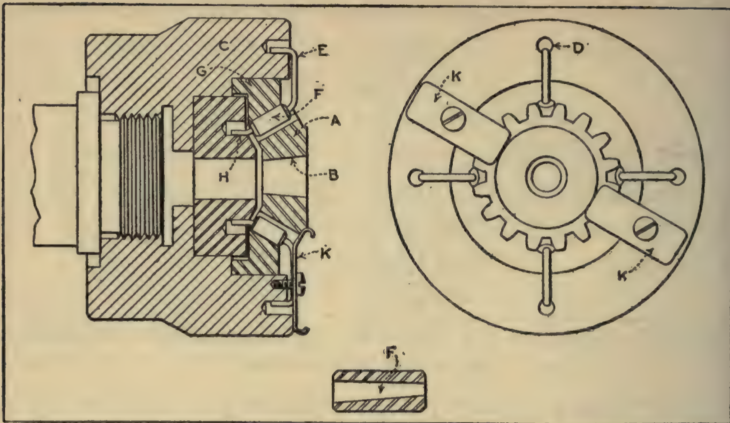


FIG. 113. ADJUSTABLE FIXTURE FOR GRINDING A BEVEL PINION

gear having an odd number of teeth by making up the blocks to suit the conditions.

Adjustable Fixture for Grinding a Bevel Pinion.—A bevel gear that has been hardened is subject to the same changes as those that may be produced in a spur gear. It must, therefore, be set up for the grinding operations in such a way as to compensate for any errors caused by the hardening process. In this case, the pitch line of the gear is generally used as a locating point. Taking the example shown in Figure 113: the work, A, is to be ground in the tapered hole, B, which must be concentric with the teeth cut on the outside of the gear.

A different type of fixture is provided for this class of work. A special nose piece, C, is screwed to the end of the spindle in the usual manner, and is provided with four holes, D, in which are inserted the round wires, E, which pass through rollers, F,

and rest against a hardened ring, G, located in the nose piece and having a suitable taper so that the center line of the roller will adapt itself to the pitch line of the gear.

An enlarged view of one of these rollers is shown in section at the lower part of the illustration. It will be seen that the center hole through the rollers is tapered for clearance only, so that a floating action is permitted, allowing them to adapt themselves to the gear. Provision is made for supporting the wire at the inner end of the chuck by means of the ring, H, and suitable holes are drilled to receive the ends of the wire. When setting up the work, A, it is placed in the chuck, and the various rolls find their location on the fixed line of the gear. The spring clamps, K, are then swung around into position to hold the gear in this location. The work is then ready for grinding.

This type of fixture also can be adapted to bevel pinions of odd or even teeth by slight changes in the roll location and by suitable rings of the correct angle, as shown at G.

Grinding Fixture for a Large Bevel Spring Gear. The bevel ring gear used in the rear axle of an automobile is likely to change somewhat during the hardening process; and it is essential, therefore, to grind it after hardening in such a way that the teeth and the center hole will be in correct relation to each other. For this purpose a fixture can be made up for grinding similar to that shown in Figure 114.

In this case, the work is located by means of a master gear, shown at A in the figure. This master

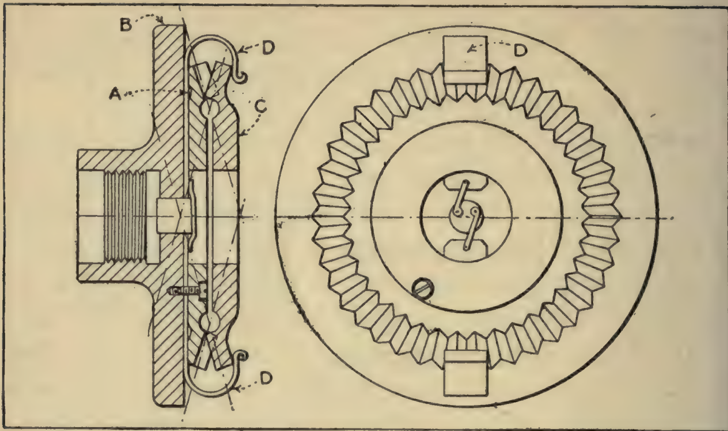


FIG. 114. GRINDING FIXTURE FOR THE LARGE BEVEL RING GEAR IN THE REAR AXLE OF AN AUTOMOBILE

gear is an exact duplicate of the gear which is to be ground, and is fastened to the faceplate shown at B, so that the pitch line of the master gear is concentric with the center of the spindle. In operation, the work, C, is placed in position against the face of the master gear and with the teeth between those of the master gear. As each of the gears is beveled, the bevels act in such a way as to center the gear in the correct position. After the location has been assured, the spring clamps, D, are adjusted to hold the work properly. As little pressure is required to hold a piece of work of this kind, these clamps answer the purpose very well and can be quickly adjusted to position. The principle shown here can be adapted to any work of this character and the work obtained by its use gives excellent results.

CHAPTER XVII

OPEN DRILL JIGS

Functions and Operation.—Strictly speaking, a drill jig is a device by means of which a piece of work may be properly located and clamped in order that a series of holes may be drilled in the work at certain fixed locations. It will be seen, then, that any number of pieces of similar shape and form can be placed one after the other in a drill jig and all the pieces will be made in such a way as to be interchangeable. Not only is a drill jig provided with the proper methods of clamping and holding the work, but there are also a number of bushings, corresponding to the number of holes in the piece, located in the jig in such a way that the drills used in the manufacture will pass through these bushings and be guided thereby. The bushings are made of hardened tool steel, and are located very carefully by a toolmaker in their correct positions to produce the holes desired.

Naturally, the shape of the work to be held exercises a powerful influence on the form of jig to be designed for the work. It is evident that a jig for a simple piece of work which can be held easily by a couple of simple clamps, is much easier to design than one which is of such shape as to require very

special methods of locating and clamping. In order to illustrate the functions of a drill jig, let us suppose that a hole is to be drilled in each end of a simple lever, and that the work is to be done in a drill jig. Let us further suppose that the workman has a drill jig before him on the table of a drill press, and that he is ready to do the work. He takes the work in one hand, then, and places it in position in the drill jig, clamping the work securely by means of the clamps provided in the jig. After this he pulls the drill jig under the drilling-machine spindle, or spindles, and proceeds to feed the drill down through the bushings provided for it in the jig. After the drill has been pressed through the work to the proper distance, the workman raises the spindle, removes the jig to a convenient position on the table, and releases the clamps which hold the work in place. This allows the piece to be taken out of the jig and replaced by another one, and the process is repeated.

When drill jigs are to be made for large work, or when a number of holes are to be drilled at different angles or from different sides, it is necessary to make up a drill jig of more elaborate form. If the work is very large and heavy, trunnion jigs are frequently employed. Jigs of this character are so made that the work is placed in position, clamped, and the entire jig is revolved on a bearing at each end, this bearing being the term from which the word trunnion is derived. A trunnion jig is mounted on a pedestal, or base of some kind, in such a way that it can be swung into the correct position for drilling. It is also provided with suitable indexing

mechanisms, in order to locate the jig properly at the various angles in which it is to be drilled. Sometimes trunnion jigs are mounted on a sort of carriage which can be rolled from one drill-press table to another, in order to take advantage of special grouping of the spindle.

In regard to the grouping of spindles, it must be remembered that many drill jigs are used on multiple-spindle drilling machines. A number of drilling machines of this character can be arranged one after the other and connected by means of a track or miniature railroad on which a trunnion jig, suitably mounted on a carriage with wheels which fit the rails of the railroad, can be rolled from one machine to the other and indexed, as previously mentioned. An arrangement of this sort can be used for such work as an automobile cylinder or crank-case, or a machine-tool gear box, or some other piece of work that requires a number of holes to be drilled in it from different sides. The advantage of such a jig is that the work is once clamped in position and is not released until all of the holes have been drilled. In this way, the jig makes it possible to obtain a number of pieces of work, all of which are drilled in exactly the same relation to each other. Drill jigs can be designed so that their work can be done on any type of drill press, from a single-spindle machine to one of the multiple type.

A number of points must be considered in the design of a drill jig: the method of locating the work in position; the method of clamping it so that it will be firmly held against the pressure of the drill and

at the same time will not be distorted by the pressure of the clamp; clearance around the work; provision for chips; easy accessibility for cleaning so that no variation in the work can be caused by chips or their accumulation on the locating point; and finally a method of clamping which will be both rapid and positive in action.

When a series of jigs is to be made, these points must all be taken into consideration if the jigging process is to give correct results. Any incorrect method of locating, or any method of clamping which tends to distort the work, may cause a great deal of trouble and expense; for even with work requiring great accuracy it is entirely possible to drill a series of holes in such a way that they will not coincide with other holes to which the work is to be fitted. Again, if the work is strained by the method of clamping, the hole will not line up properly with the other work and a great deal of unnecessary fitting must be done when the parts are assembled.

In taking up the more common types of drill jigs, let us consider that the two most general types are the open and the closed jigs. An open jig is one in which the work is held in such a way that it is not enclosed. A closed jig is one of the box type, where the work is placed in a sort of box or frame and is usually drilled from several sides in the same setting.

A Simple Plate Jig.—The work shown at A, Figure 115, is a cast-iron flange which is to be drilled with six holes, B, located in a circle around one face of the flange. This is an extremely simple piece for

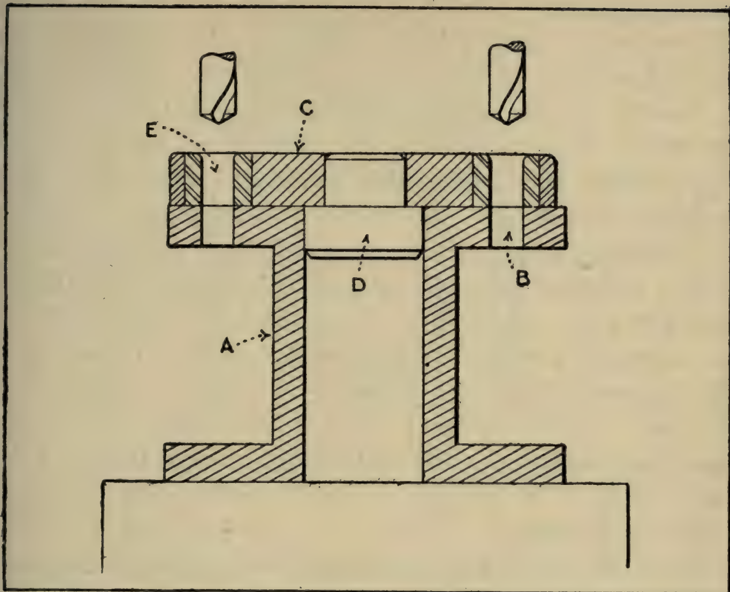


FIG. 115. SIMPLE PLATE JIG

which to make a jig and, therefore, it is used as an example to show what simple forms may be used for jigging purposes.

In this case, the work has been previously bored and reamed, so that the jig plate, C, can be located directly on the upper flange by means of a plug, D, which enters the roll. The jig plate is provided with a series of bushings, E, so located in the plate as to give the resired location to the hole. For a piece of work of this kind no clamping device is necessary, as the work is usually done on a multiple-spindle drill press, each spindle of which contains a drill of the proper size for the work. These drill spindles

are adjustable, so that they can readily be made to correspond to the holes in the jig. In operation, a jig of this kind is simply dropped on the work which is located on the drill press table, and immediately thereafter the spindles of the drill press are brought down until they enter the bushings; after this the feed is started and the work is completed without any clamping device being necessary. The pressure of the drill is sufficient to hold the work in position, and after the holes have once been started there is no necessity for any method of clamping to keep the jig properly located. Jigs of this kind are suited to many kinds of work that have been previously machined, as indicated, and also to work that has a finished face on which to rest it while the drilling is taking place.

Plate Jig with Supplementary Supporting Ring.—Another type of plate jig, more suited to work that would be unstable without support while being drilled, is shown in Figure 116. This piece of work has been previously finished on both sides of the flange, B, and also on the outside of the hub, C. It will be seen, however, that the piece could not be drilled very well without some sort of support, because the radius of the hole, E, is out beyond the base of the hub, A, and if the work were to be drilled without any support, it would be likely to tip one way or the other unless all the drills were exactly of the same length. In order to overcome any tendency of this sort, a cast-iron ring, F, is made to act as a support for the work. This ring is made of sufficient diameter and stability to allow the work to

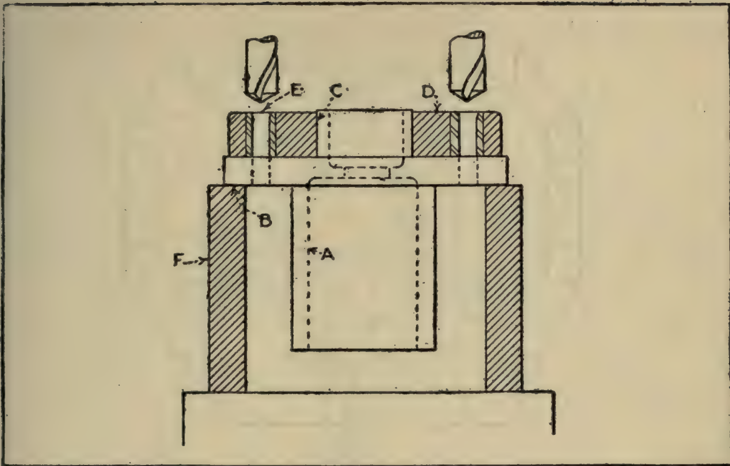


FIG. 116. PLATE JIG WITH SUPPLEMENTARY PLATE

rest on the flange at B and be supported thereby. The drill-jig plate, D, in this case, is made so that it will slip over the hub, C, and is provided with a series of bushings, E, arranged in circular form to give the correct spacing of the holes.

In some cases, the holes to be drilled may be of several diameters, and drills of corresponding diameter are used. However, when an occasion of this kind arises, some method of location must be provided, both for the work and for the drill-jig plate in order that the correct bushings may be located properly under the corresponding drill.

This kind of jig is usually used on a multiple-spindle drill press, with the spindles grouped to the correct radial setting. Adaptations of the two forms of jigs just mentioned, Figures 115 and 116, may be made to cover a variety of cases. Such jigs are

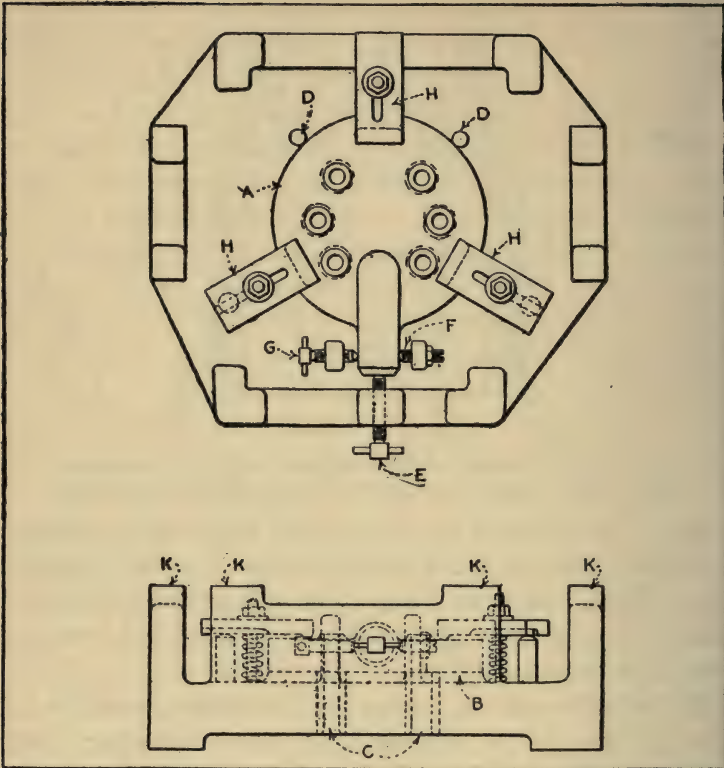


FIG. 117. DRILL JIG FOR AN OIL-PUMP COVER

cheap in their construction and answer the purposes for which they are intended very well indeed.

Drill Jig for an Oil-Pump Cover.—The work shown at A, Figure 117, is an aluminum oil-pump cover which has been previously faced on the surface, B, but has not been turned. Due to the fact that only one surface on this piece has been machined, it is necessary to locate from this surface for the opera-

tion of drilling the six holes shown at C. In order properly to accomplish a correct location for this work, the vee principle is used.

In the example shown in Figure 117, the two pins at D are used as locaters of this kind. The work is forced against or between these pins by means of the thumb screw shown at E, and is further located by means of the stop-screw, F, against which the boss is clamped by means of another screw, G. The clamps, H, are then tightened, thus holding the work firmly against the face of the fixture and down on the surface, B. With the work in this position, the entire jig is turned over onto the legs, K, on which it rests while the drilling operation takes place. These legs are a part of the base casting of the jig, and are surfaced in such a way as to provide an ample means of support which is, at the same time, parallel with the surface, B. Bushings are provided for the holes at C, as in the former instances described. It will be seen that after the jig has been turned over, the pressure of the drills comes entirely against the clamps, H. These clamps, therefore, must be sufficiently strong and heavy to withstand the pressure.

Jigs of this kind are very useful for many kinds of semi-cylindrical work where there is a single finished surface and a series of holes arranged more or less centrally about the center of the piece. Applications of the principles shown in this jig can be made to a great variety of work.

Open Jig for a Lever.—Jigs designed for drilling holes in levers are of two kinds: those which locate from the work in its unfinished state or which locate

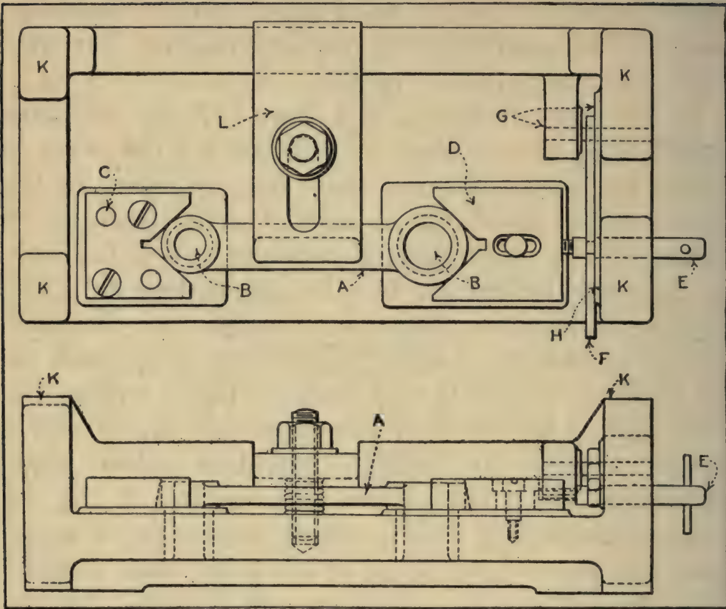


FIG. 118. OPEN JIG FOR A LEVER

on bosses at either end of the lever; and those which locate for a single drilling operation of one end-hole from a previously bored or reamed hole in the other end. Both of these jigs are in common use and will, therefore, be described separately. The type mentioned first is shown in Figure 118. In this case the lever, A, has been finished by straddle milling the side of the bosses at each end. The jig shown is for the purpose of drilling the two holes, B, at each end of the lever.

The method of locating used for this piece is a vee block, C, in which the boss at one end of the

lever rests. The other end of the lever is located and clamped simultaneously by means of the sliding vee-block, D. This vee-block is chased up into position by means of the thumb screw, E, located in a swinging latch, F, between the bosses, G, through which a pin is passed. An additional support is given the latch at the other end on the lug, H. After the work has been located as mentioned, it is clamped firmly by means of the wide clamp, L, which is slotted so that it can be pushed back out of the way to allow the piece to be placed in position. When the work has been clamped as indicated, the entire jig is turned over, so that it rests upon the two feet, K, after which the holes are drilled through the bushings indicated.

This type of jig is in common use, with certain modifications in regard to clamping and locating in accordance with the nature of the piece to be drilled. It is comparatively inexpensive and gives excellent results.

Open Jig for a Lever with Stud Locater.—The lever, A, Figure 119, is of similar shape to that shown in Figure 118, but it is of larger size, and the end, B, has been bored and reamed in a previous operation. It is, therefore, necessary to locate from this hole to drill the small end, C. A stud, D, is placed in the jig body, and the work is placed over it as indicated. The small end, C, is located by means of a sliding vee-block, E, which is forced up against the boss by means of a thumb screw, F. The work is held in position and supported against the pressure of the cut by means of the clamp shown at G. As in the

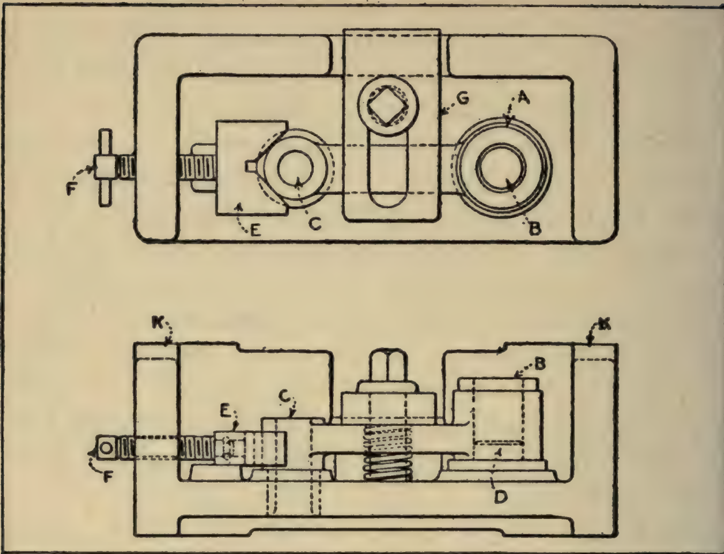


FIG. 119. OPEN JIG WITH STUD LOCATER

former case, after the work has been located in the jig it is turned over, so that it rests upon the feet, K, in which position it is drilled. Jigs of this kind are nearly as common as that shown in Figure 118, and their application to many shapes of levers will be apparent.

Open Jig for a Small Bracket.—The work shown at A, Figure 120, is a small bracket which is to be drilled at B, C, and D. The holes, B and C, are in one plane, and the hole, D, is in another. Therefore, the jig must be so made that it can be turned on one side for the latter hole and on another side for the holes at B and C. The use of a vee-block is seen in this fixture at E, and the rounded angular end of the

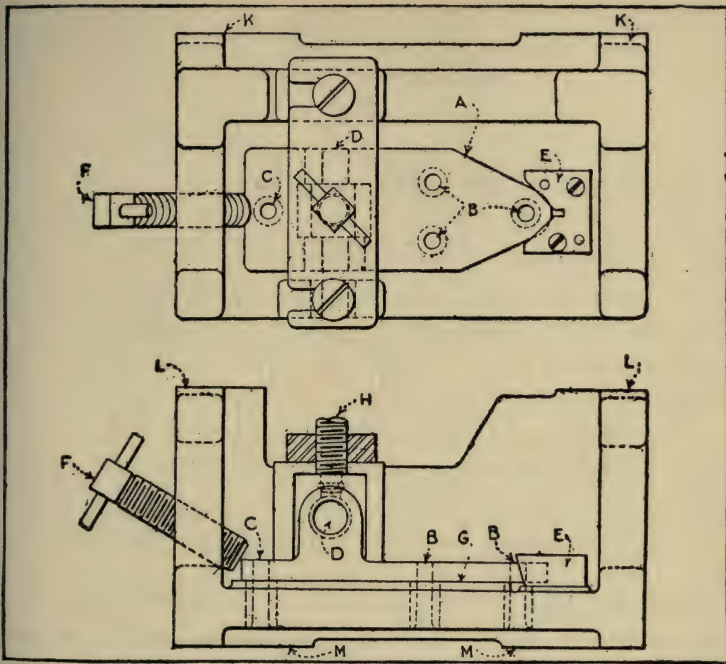


FIG. 120. PLAN AND SECTION OF OPEN JIG FOR A SMALL BRACKET

work rests in this block as it is forced there by means of the set-screw shown at F. It will be seen that this set-screw is placed at an angle and also that the vee-block, E, has an angular face. The purpose of this is to make sure that the work will be held down firmly and located correctly. The work rests on the flat milled surface, G, and suitable bushings are provided for the various holes. An additional clamp is provided at H in order to make the clamping action more positive. Legs are provided on the side of the jig at K and also at L, so that the work can be

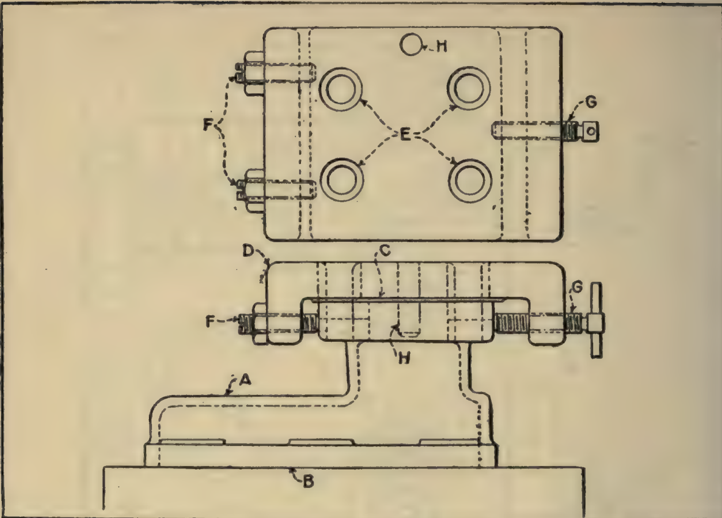


FIG. 121. SET-ON JIG FOR A TRANSMISSION-CASE COVER

drilled in the correct positions. Additional legs are also made at M for purposes of setting up the work.

Set-on Jig for a Transmission-case Cover.—When a large piece of work is to be handled and a small portion of it only is to be drilled, a set-on jig is advantageous. In the design of a jig of this kind it is always necessary to consider the bearing which the work itself will have on the table of the drill press, in order that the pressure of the drills as they enter the work may not be in such a position as to cause the work to topple over or tip on one side.

An example of this kind is shown in Figure 121. In this case, the work, A, has been previously finished by milling along the surface, B, and also on the face, C. At C, four holes are to be drilled as

shown at E in the upper view. The surface, B, is sufficiently solid to rest on the drill-press table without difficulty.

The drill jig is made of cast iron and consists of a pipe, D, with lugs at each end through which the set-screws, F, are passed to act as an end-stop for the jig when it is placed in position on the work. Another stop-pin is placed on the other side of the jig plate, as shown at H in the upper view, and in placing the jig plate on the work this pin is brought up against the side of the work before the set-screw, shown at G, is tightened. As this set-screw is tightened it will be seen that the entire jig is clamped in place on the top of the work. The jig plate is provided with a series of bushings, E, through which the drills are passed as the four holes are drilled. This is a very simple type of jig, but application of the principle shown can be used on many other cases for work of similar kind.

Set-on Jig for a Gas-Control Plate.—Set-on jigs are sometimes used for small as well as for large pieces when the size of the work is such that it can be used to advantage. In designing a jig of this kind care must be exercised to see that there is sufficient stability to the work itself to permit placing and supporting the jig upon it. Figure 122 is a very good example of a piece of work which can be drilled with this type of set-on jig. The gas-control plate, A, in this case, has been finished in a previous operation, so that the surface, B, is perfectly plane and can therefore be used for setting up the work. The jig is placed on the top of the piece as indicated in

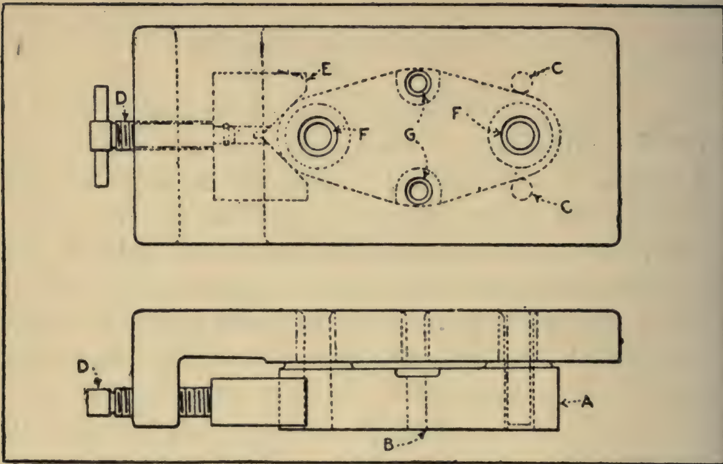


FIG. 122. SET-ON JIG FOR SMALL PIECE OF WORK

the illustration, and the two pins, shown at C, in reality form a sort of V against which the work is forced by means of the set-screw at the other end of the jig. This set-screw, D, forces up the work and locates it at the same time by means of the vee-block, E. A series of bushings are arranged to drill the holes, F and G, in the top view.

It will be seen that when this jig is to be used, it is only necessary to place it in position on top of the work while the work is resting on the drill press table and then to tighten the thumb-screw, D. After this has been done the jig can be readily moved under the spindles of the drill press, in which position the work can be drilled without difficulty.

The number of other jigs which could be classed under the heading of open jigs, is so great that it is out of the question to enumerate the different types

in a book of this kind. My effort, therefore, has been to show new forms of open jig, in order that the discriminating reader may be able to form an idea of the various types and their application to work of ordinary nature. Speaking broadly, an open jig can be made for almost any piece of work when holes are to be drilled from not more than three directions. As the usual thing, however, open jigs are designed for pieces that are to be drilled in one or two directions only

CHAPTER XVIII

CLOSED JIGS

Bushing for an Oil-Pump Shaft.—In the previous chapter a few varieties of open jigs were described, but by no means all types were mentioned. In this chapter, also, it will be impossible to enumerate every type of closed jigs, and yet an attempt will be made to cover the subject in a broad way, so that the reader will be able to get a good idea of the variety of jigs.

Referring to Figure 123, let us assume that the bushing shown at A, has been previously bored and reamed in the hole, C, and that the end, B, has been faced. Let us also assume that the outside of the work has been completely finished to the form shown, and that the upper end has also been faced. The work in this case is located on the previously finished hole at C on a small stud, and it rests against the surface, B, on the locating stud. While in this position, it is clamped by means of the set-screw shown at H. A button on the end of the set-screw bears against the end of the piece.

This type of jig is arranged in such a way that holes can be drilled in the work at two different angles. The jig is turned over on the legs, F, while the hole located by the bushing, D, is drilled. After

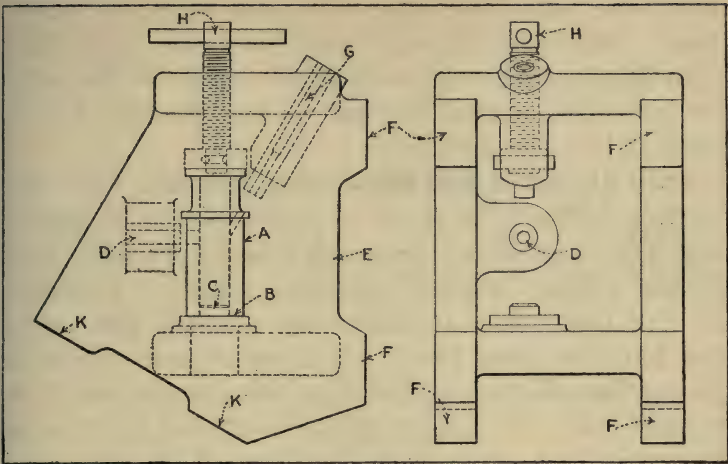


FIG. 123. BUSHING FOR AN OIL-PUMP SHAFT

this is done, the jig is turned over until it rests upon the legs, K. In this position, the drill is guided by the long bushing shown at G. As this bushing is so very long, it will be noticed that it is relieved to a size a little larger than the drill for a good proportion of its length.

As the piece of work shown in this illustration is cylindrical in its general form, it does not make any difference how it is located radially, so that it is only necessary to slip it on to the stud and tighten the clamp screw, H, before starting the work. A drill jig of this kind can be used for many kinds of bushing work when oil holes or other holes of similar kind are to be drilled. It forms an excellent example of a simple type of closed jig. Naturally, such a jig is used on a drill press, either with a couple of spindles in which the different size drills

are placed and used one after the other, or else a magic chuck or its equivalent is used in a single spindle machine, and sockets for each of the drills are provided so that one can be interchanged for the other while the spindle is in motion.

Drill Jig for a Rod-Supporting Bracket.—The supporting bracket for a rod or shaft, shown at A, Figure 124, has been previously machined in a hole which extends entirely through the hub indicated. At the time when the hole was reamed, the end of the hub was also faced. In a subsequent operation the surface, K, was milled in a definite relation to the reamed hole. In the operation indicated by this jig, the work to be done is the drilling of the two holes, B, and also the one from the opposite side as indicated at C.

As the hole, F, shown entirely through the hub has been previously located from the milled surface, K, when it was machined, it is obvious that a location from the hole and the milled surface can logically be considered as the correct method of locating for the present operation. In order to support the flanges while they are being drilled, the two set-screws, E, operated by the workman's fingers are used. These set-screws are conical on the end, so that they set up a slight wedging action and hold the work securely. The piece is slipped upon a locating stud in the large hole, and after it has been clamped against the opposite end of the hub by means of the C-washer shown at F, by the nut indicated, the set-screws, E, are tightened as previously mentioned. When drilling the holes, B, the jig is set

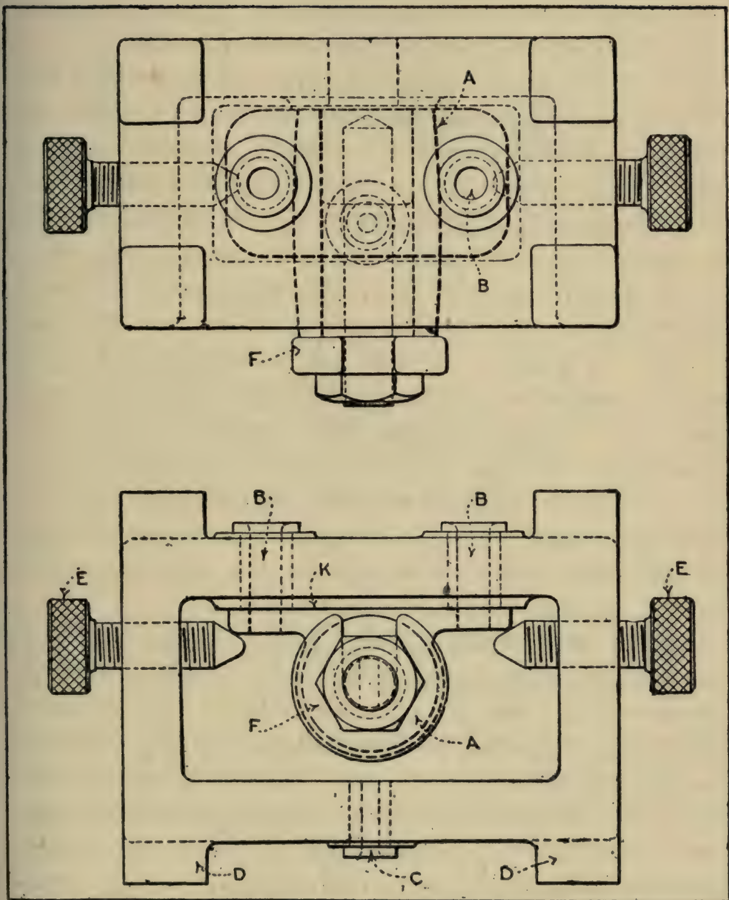


FIG. 124. DRILL JIG FOR A ROD-SUPPORTING BRACKET

up upon the legs, D. When the hole, C, is to be drilled, the entire jig is turned over until it rests upon the legs on the opposite side. This completes the drilling operations on this piece of work.

This is one of the simplest types of jigs which can be devised, but it can be made to give excellent results in ordinary practice. A point which should be mentioned in connection with a jig of this sort is that the surface on the jig shown at K should be so milled in relation to the center stud on which the work locates that there will be a slight amount of clearance between the surface of the piece and the pad on which it locates. A very slight amount of tipping may be caused when the thumb-screws, E, are tightened; but in actual practice this amount would never be sufficient to cause any trouble, so that the jig can logically be considered of good design. In addition, this jig is easily made and easily cleaned, and chips are not likely to accumulate on the locating point, thereby causing errors in locating.

Jig for Automobile Hand Lever.—Sometimes an occasion arises to make a jig which can neither be considered an open jig nor yet a closed jig. Such an example is indicated in Figure 125. In this example, the jig is a kind of half and half type, and is not really one of the two types, but is midway between them. In this case, the work, A, is a hand lever used for operating a pull rod or latch on the brake lever of an automobile. Previous to the operation of drilling, the work has been milled on the surface, F, and it is therefore safe to use this surface as a locating point in the drilling operation. The piece,

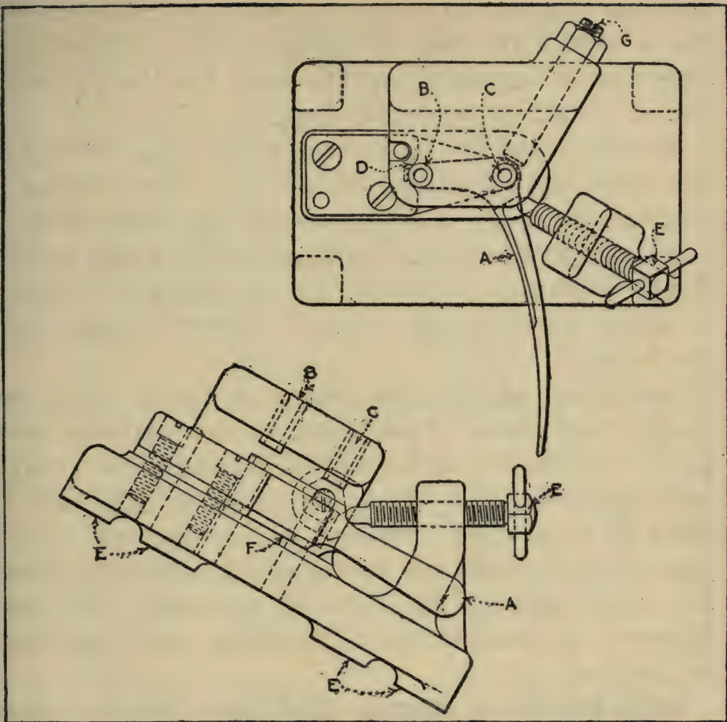


FIG. 125. JIG FOR AN AUTOMOBILE HAND LEVER

therefore, is laid on the surface, F, in the jig as indicated, and is pushed over into a vee-block, D, by means of the set-screw, E. This set-screw strikes against a corner or fillet on the lever in such a way as to force the work into the vee-block and at the same time to throw it over until it strikes the end of the set-screw, G. It will be seen that then the set-screw, G, acts as one side of a vee, the other side of which is formed by the thumb-screw, E. All of

the clamping action is accomplished by means of this one screw in the case mentioned. Little difficulty is experienced in setting up the work for the operation and in obtaining a correct location.

The work which is to be done in this setting of the piece is the drilling of the two holes, B and C, and the entire jig is set up on the leg shown at E, in the lower portion of the illustration, when the work is done. Bushings, naturally, are provided at B and C to guide the drill and to insure correct locations for the hole.

Nearly all of the jigs shown so far in these two chapters are made of cast iron, as this material lends itself to a variety of forms and can be made cheaply and quickly. But the same types of jigs can be built up from steel if desired, and in the case of gun jigs and of jigs for use with a great many dull pieces, the steel built-up jig is to be preferred. Its cost, however, is prohibitive in anything but very large production.

Drill Jig for a Bearing End-Cap.—When a piece of work has been previously machined and it is necessary to locate it for a drilling operation subsequent to the other operations on the work, it is essential to locate the piece by means of the finished surfaces. An excellent jig for a piece of work of this kind is shown in Figure 126. In this case the work, A, has been previously faced at B and has been recessed at C. It is necessary then to locate the work for the drilling of the four holes shown at F, by the previously finished surfaces. The method of doing this is to set the work upon a shallow stud or plate,

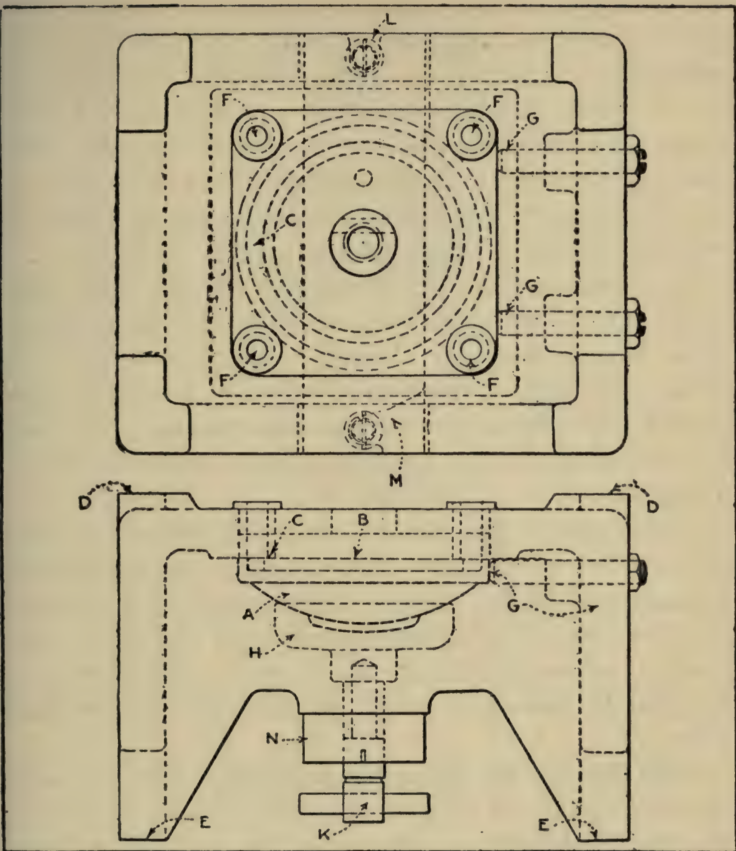


FIG. 126. DRILL JIG FOR A BEARING END CAP

locating it by means of the recess at C, and clamping the work by means of an equalizing collar, H, operated by the thumb screw, K.

In placing the work in the jig, the square side of the piece strikes against the two set screws, G, thus giving a squaring-up effect. It will be seen that the

action of the clamp collar, H, is such that when the thumb screw, K, is tightened, the entire collar rocks sufficiently to permit an equally distributed pressure on the work. The thumb screw, K, is mounted in a strap, N, which extends entirely across the jig. This strap is slotted at L and M in such a way that it can be quickly removed when placing a piece of work in the jig or removing one from it.

In operation the jig is set up on the four legs shown at D, and the work is slipped into position. After this is done the strap is put in place and the thumb screw, K, is tightened. The entire jig is then turned over until it rests on the legs, E. Bushings are provided at F to guide the drills to their proper positions.

This type of jig can be used for many varieties of work of a similar character, the only variation necessary is in the manner of locating the piece and in little details of clamping, and so on. The type itself is a common one, the use of which can be adapted to numerous kinds of work of similar character.

Drill Jig for an Eccentric Bushing.—The eccentric bushing shown at A, Figure 127, is used as an adjusting bushing for obtaining the correct relation between the worm and worm-gear sector of an automobile steering gear. This piece of work has been previously bored and reamed at B, and has been faced on the end. The drill jig shown in the illustration is for the purpose of drilling the hole, D, in the end of the arm as indicated in the illustration. The body of the jig is provided with feet, K, on

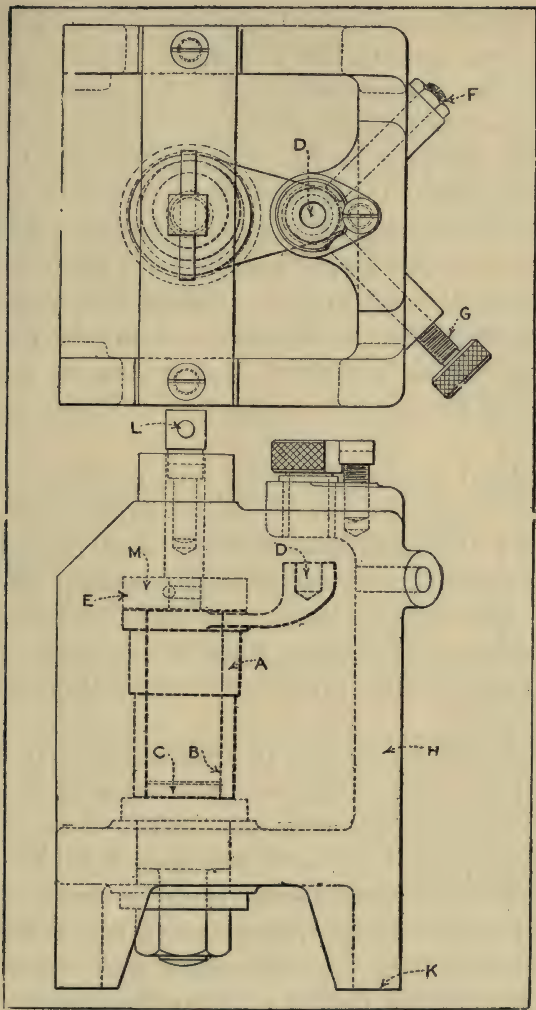


FIG. 127. DRILL JIG FOR AN ECCENTRIC BUSHING

which it rests on the table of the drill press. The work is located on a short stud shown at C, and is clamped down upon the shoulder of the stud by means of the thumb screw, L. This thumb screw operates a square plate, M, which bears against the top of the bushing at E. The correct location for the arm in which the hole is to be drilled is assured by means of the thumb screw, F, which acts as a stop for the end of the lever, and also by the screw, G, which forces the work over against the screw previously mentioned. A suitable bushing is provided at D, which is so arranged that it can be removed and replaced by another bushing of suitable size for the reamer.

The method used in drilling and reaming a piece of work in a jig of this kind, is first to drill the work, using the drill-sized bushing, and immediately after this operation to remove the bushing and substitute a larger one of the proper size for the reamer. This reaming of the hole sizes it correctly to the given diameter and produces a smoothly finished piece of work.

The slip bushing shown in this illustration is one of many types which can be used when it is necessary to remove one bushing and replace it by another, as in reaming a hole after it has been drilled. There is very little difference in the types of bushings, the essential point in design being that the bushing shall be so made that it can be easily and quickly removed and secured firmly when in position.

Drill Jig for a Radius Bracket.—A somewhat odd-shaped piece of work which requires a rather pecu-

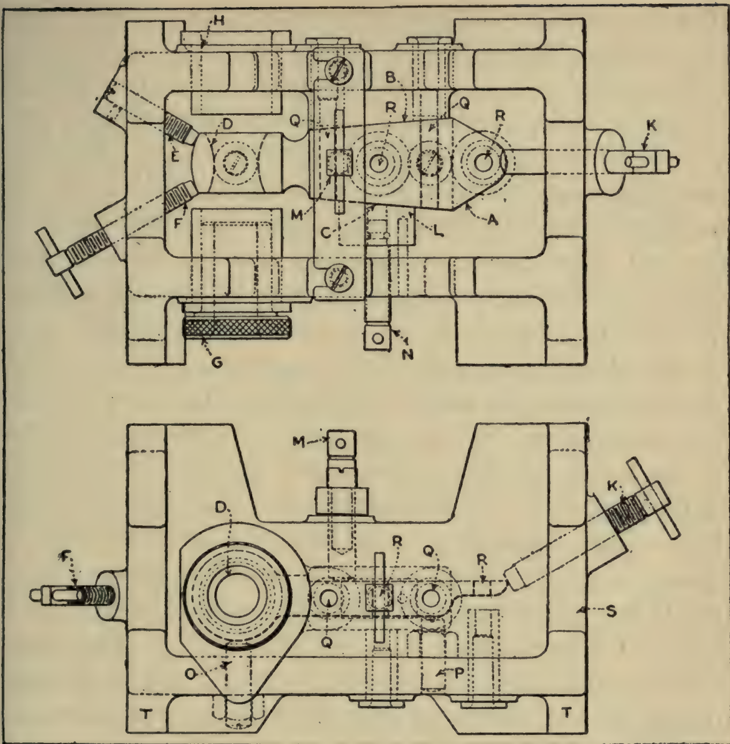


FIG. 128. DRILL JIG FOR A RADIUS BRACKET

liar type of jig is shown in Figure 128. The work, A, has been previously machined on the surfaces, B and C, to the angle indicated. It is necessary, therefore, to locate it by the previously finished surfaces, and also to provide an end location and clamp the work securely in position in the jig. The end location is assured by means of the stop screw, E, and by the thumb screw, F. This thumb screw, F, is hand operated after the work has been thrown over

into the position shown, by means of the screw, K, at the other end of the jig.

The work to be done in this operation is the drilling of the hole, D, through the angular side of the piece, and also two other holes indicated at R. Suitable bushings are provided for all of these holes, as can be clearly seen in the illustration. The bushing used for the hole, D, is of the slip variety and is indicated at G. On the opposite side of the jig a bushing, H, is located for a counterbore which is used in one side of the hole, D. In operation the work is placed in the jig until the surface, B, rests against the angular part of the jig, after which the set screw, K, is used to move the work forward in the jig until it strikes the set screw, E. The thumb screw, F, is then brought up to make a contact and to assist in supporting the work, and the screw, N, is used to bring up the angular shoe shown at L, against the angular side of the work. The work itself rests on the set screws, O and P, and is clamped down by the screw at M. It will be seen that the position of the screw, K, is such that it tends to throw the work down against the stop and over against the two set screws, E and F. A jig of this kind is provided with feet on the sides opposite to all points which are to be drilled, so that the jig will have a firm foundation on which pressure can be brought to bear.

In drilling the piece shown, the slip bushing, G, is first used, and a large hole is drilled through the portion, D. After this the bushing is removed, and a counterbore of special shape is fed down through the

liner bushing indicated. The jig is then turned over and the process is repeated through the bushing, H. In like manner the other holes are drilled by spindles in a multiple-spindle drilling machine, these spindles being arranged in proper location to give the correct spacing for the various holes. Jigs of this character are used for many kinds of work and can be adapted to suit different conditions.

Drill Jig for a Crooked Lever.—The work shown at A, Figure 129, is a crooked lever, both ends of which are to be drilled and reamed as shown at B and C. In addition to these two holes, there is a smaller hole at F, which is to be drilled in the same setting of the work. For this operation the lever is placed in the jig through the open side and rests on the finished pad at each end. At the large end, the flat surface of the work rests on a fixed support, as indicated, but at the smaller end, B, the support is assured by means of the screw bushing shown at H. After the work has been placed in position, this screw bushing is jacked up by means of a pin placed in the holes shown at O.

The location of the work is gained by the V-blocks at E. It will be noted that the V-block at this end of the lever is fixed, but at the other end there is a floating member attached to the thumb screw, L, which also acts as a V-block locater. This is clearly shown in the upper view. After the work has been placed in position and located as mentioned, the thumb screw, D, is turned down firmly against the web of the lever. The work is now in position to be drilled, and the jig is turned over on the legs

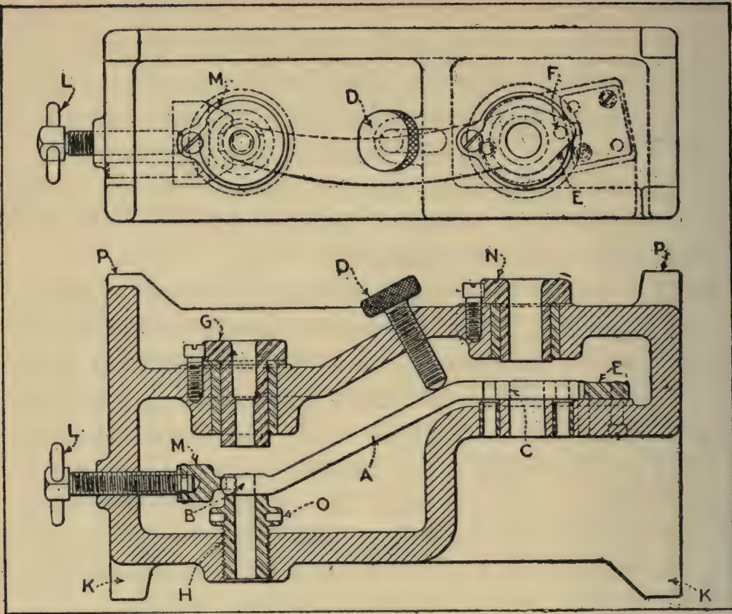


FIG. 129. DRILL JIG FOR A CROOKED LEVER

shown at P and K for the various drilling operations involved.

The principles involved in this jig are identical with those which can be applied to many other varieties of lever jigs. Naturally it is always necessary to adapt any jig to the work on which it is to be used, but the principles underlying the design of jigs of this kind are much the same, and suitable adaptations can be made for various conditions of work in the shop.

Large Trunnion Jig.—When the work to be handled is of large size and somewhat awkward in shape, it is sometimes desirable to hold it in some

sort of jig which can be easily loaded. After the piece has been placed in the jig, the entire mechanism can be turned over by means of a crank or other mechanical device, so that it will lie in the correct position under the drill-press spindles. Furthermore, a jig of this kind should be arranged so that several sides of the work can be drilled without removing the piece from the jig and without any necessity for more than one operation of clamping. A suitable indexing device can be made, so that the accuracy of the holes which are to be put in from different sides of the work can be assured without difficulty.

A jig of the kind mentioned is generally termed a trunnion jig. The possibilities of a trunnion jig are dependent on the number of sides of the work which are to be drilled. When the work is such that it must be drilled from four or five directions, it is possible to make a double trunnion jig which can be indexed in several directions to provide for the drilling of holes from several different angles. However, a jig of this kind is more or less complicated, and it does not always prove a profitable investment to make one unless the work is in sufficient quantity so that the expense incurred will be offset by the saving in the manufacturing time. Nevertheless, drill jigs of the trunnion type having a suitable bearing on which they can be swung, are more or less common.

An example of a trunnion jig of this kind is shown in Figure 130. The work, A, in this case is a transmission-case casting made of aluminum and pre-

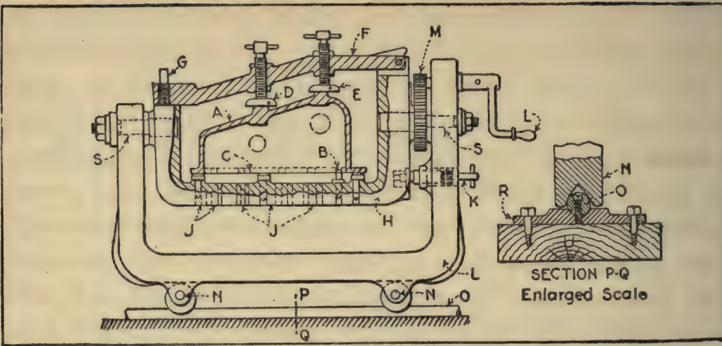


FIG. 130. EXAMPLE OF TRUNNION JIG FOR A TRANSMISSION CASE COVER

viously machined along the surface, C. It has also been drilled at two points for dowels, as indicated at B, and these holes are used as locating holes for the work when the piece is being drilled. In locating the piece, A, in the jig, the position of the entire jig is as indicated in the illustration. The work is placed in the U-shaped casting, H, locating on the dowel pins at B. After it has been placed in position the latch, F, is swung down into position and the thumb screw, G, is tightened to secure the latch. After this the two thumb screws shown at D and E are tightened to make the work absolutely secure in the jig.

The piece is now ready to be drilled, but it will be noted that the holes, J, which are to be drilled are in the under side of the work. The entire unit, H, is hung on two bearings at S, and these bearings are situated in the carriage, L, which is furnished with wheels, N, traveling along a track located on the bed of the drill press. An enlarged section of the

track is shown at P-Q, which makes the construction of this part of the jig clearly apparent. The purpose of the track is to provide a means of moving the jig from one machine to another when one part of the work has been drilled by a series of spindles and another set of holes is to be handled on another machine.

When the jig is to be indexed preparatory to drilling, the pull pin, K, is removed from the bushed hole indicated, after which the handle, L, is operated, thus indexing the entire jig by means of the gears shown at M. This indexing operation turns the entire jig over, so that it is in the correct position for drilling the work.

An arrangement of this kind will show very satisfactory results when a high production is to be obtained on a given piece of work and when the piece is of such size and shape that it can not be conveniently handled in a single operation. By arranging a track like the one indicated in the figure, and by suitably fastening this track on cradle castings, like those shown at R, the round shaft, O, makes an excellent track used in connection with the grooved wheels. It is entirely possible, with an arrangement of this kind, to set up two or three machines with properly-spaced spindles so that the jig can be rolled from one machine to the other with very little loss of time and without the necessity for more than one setting of the work.

In this chapter an attempt has been made to describe a variety of drill jigs which are in common use, but it is eivdent that it is entirely out of the ques-

tion, in a work of this kind, to go into every matter of design in great detail. Enough examples have been given, however, to make the subject as clear as the space will permit and the examples given have been selected with a view toward simplicity and variety.

CHAPTER XIX

LUBRICATION OF CUTTING TOOLS

Necessity of Lubrication.—If a man has an automobile, a bicycle, or some other piece of machinery and wishes the machine to be at its best, the first thing that he considers is the proper lubrication of the various bearings so that the mechanism will run as smoothly as possible. Now, in cutting any piece of metal the question of lubrication also arises, for as the cutting tool is in constant contact with the metal which is being cut, it is obvious that a great deal of friction is produced. The friction heats the tool, and if the amount of heat generated is excessive, the result will be disastrous to the cutting tool and eventually result in its ruin. It is necessary therefore on some kinds of material to provide a suitable cutting lubricant in order to carry away the heat generated by the friction of the tool and to make the work easier. Certain kinds of material do not require lubrication, but on others it can be used to great advantage.

The question of lubricating a cutting tool is of so great importance that it must be thoroughly considered. A great many points come up in connection with cutting lubricants for different classes of materials. It is out of the question to attempt to prescribe

a cutting lubricant which will be suited to any particular kind of metal without knowing the exact nature of the alloy of which the metal is composed. Let us suppose that some one were to ask the question, "What is the best cutting lubricant for aluminum?" It would be difficult to answer this question absolutely without knowing of what alloy of aluminum the casting was composed.

This reminds me of an anecdote which I once heard of two Englishmen who were in this country for the first time and who were talking about the peculiarities of Americans in general. The two men were in a railroad station at the time, and one remarked to the other, "They say that an American always answers a question by asking another one." "That seems very improbable," replied the second. "Well, let us see if this is really the case. I'll try it now." So he strolled over to the ticket office and asked the ticket agent, "I want a ticket. How much is it?" And the agent replied, "Where to?"

So in the matter of cutting lubricants for different materials, if I were asked to state the type or kind of lubricant best suited to a given material, I would have to ask what the composition of the casting was before it would be possible to name the proper kind of lubricant to use on the work.

There is considerable difference of opinion among manufacturers as to what particular lubricant is better for certain classes of work. However, a variety of lubricants have been proved to give excellent results, and although the proportions of their component parts may vary somewhat, the ingredients

themselves are very similar. In this chapter we will describe a number of lubricants which have been used with success on different kinds of materials. Although modifications of the formulas herein given may be found advisable in some cases, the ones given are thoroughly practicable for commercial purposes.

Composition of Cutting Lubricants.—In the first place it must be remembered that all materials do not require lubrication. Cast iron, for example, is not lubricated to any extent. (Some manufacturers have attempted to use various lubricants on cast iron, but I do not believe that the results obtained have been at all convincing. At any rate, cast iron is generally cut dry.) Brass is usually cut dry. Aluminum is sometimes cut dry and at other times it is cut with a lubricant.

We have decided that the purpose of a cutting lubricant is twofold, one of the purposes being the lubricating of the cutting tool, thereby eliminating the friction to a certain extent, and the other is a cooling action intended to keep the cutting tool in such condition that it will not be ruined by too great heat. Now, in discussing the kinds of lubricants used for these purposes, we can consider that practically only two kinds of lubricants are in use. One of these is composed of lard oil or mineral oil, or of mixtures of mineral and lard oil. The other compound is of a soapy nature and was devised in order to provide a greater cooling effect than that obtained by the use of oil only; at the same time it carries sufficient grease so that it provides a certain amount of lubrication also.

A solution of sodawater was formerly used as a cooling medium, but as this compound possesses little lubricating action it has been gradually replaced by other compositions carrying greater percentages of grease. A number of solutions are on the market at present, and most of these are in the nature of emulsions. A saponaceous, or soapy, fluid is formed by means of potash, or soda, added to animal oil which is readily soluble in water. In mixing a compound of this kind it is only necessary to dissolve soap in mineral oil and then add water sufficient for the purpose in hand.

It is important in mixing a solution of cooling or cutting compounds for any kind of work to make sure that the action of the compound is not such that it will cut away the lubricating oil used in the bearings of the machine. Unless care is used in making a proper mixture, there is some danger of obtaining so "sharp" a mixture that it will eventually remove all the lubricating oil from whatever portion of the machine it touches, and the natural result will be that the machine itself will be seriously injured through friction.

The different compositions of cutting lubricants as used by various manufacturers are much the same, although their method of mixing and the various proportions of the ingredients may differ somewhat. In general, the following formulas will be found to give good results, although the mixing of the compound may vary according to the amount of water which is used.

Bar stock or machine-steel forgings can best be

cut with a mixture of lard oil, borax, and water, or lard oil or mineral oil can be used alone.

Steel castings, and bronze or malleable iron can be cut to advantage with a lubricant composed of mineral oil alone.

A mixture made of half lard oil and half kerosene will prove the best for aluminum castings, and produces a very smooth cutting action that is much better than kerosene alone. Kerosene alone is advocated by many manufacturers, but it is not equal to the lubricant mentioned.

Wide-faced and forming tools seem to give better results when lard oil alone is used with them, and tools that are made of carbon steel seem to have longer life with this lubricant.

Lubricating Compound for Steel.—An excellent borax compound for steel is made as follows: Dissolve one pound of borax in seven gallons of hot water and allow the mixture to cool. After it has cooled, add to it one gallon of lard oil thoroughly mixed. Enough borax should be used to make the oil and water mix thoroughly. The quality of the lard oil used will affect the amount of borax, and hard or soft water will also make a difference in the proportions. The quantities mentioned are safe to start with, although slight variations may be needed to suit particular cases.

A convenient method of mixing cutting lubricants of this kind is to use forty gallons of hot water to seven pounds of borax, mixing the solution in a fifty-gallon barrel. When the solution has cooled, seven gallons of lard oil can be stirred in, after which it is

ready for use. As previously mentioned, the greatest care should be used in the amount of borax, because too much borax has a tendency to cut away the lubricating oil used on the machine, so that trouble may be caused from imperfect lubrication of the machine parts. In general, however, it will be found that a tool will wear away more quickly when borax solution is used than if pure lard oil is used, but the cooling action on the tool is considerably greater with the borax water.

Cooling by Lubrication.—The matter of cooling the tool and lubricating it at the same time is of so much importance that it is well to speak at this time of the particular necessity for proper lubrication when heavy cuts are being taken. As an example, let us consider that a piece of steel is being cut with a heavy feed and at about the maximum speed, and it is desired to select a suitable lubricant for it. As the friction produced by a heavy cut is so much greater than if the cut were to be a light one, it is apparent that in order to produce as good a lubricating effect as possible it will be necessary to use an oil rather than a borax compound. But if the same piece of steel is being machined at high speed and the amount of stock which is being removed is not very great, the heating of the tool will be very much greater, and a borax solution will therefore be found to give better results.

Another factor that is worthy of comment in regard to the use of cutting lubricants on machine tools, is the matter of power consumption. Authoritative data on this subject is difficult to obtain, but

as it is known that a machine will run easier with oil in the bearings, I am firmly convinced that a cutting tool will remove metal easier if it is properly lubricated. Experiments that have been made along these lines have been widely different in the results obtained, and to my knowledge no absolute tests under careful management have been made that give contradictory data.

Lubricating Stream to Remove Chips.—Another function which should be mentioned is the use of a stream of cutting compounds to wash away the chips that are generated by the tool. This item is more serious in some cases than in others. For example, take the drilling of a deep hole in a piece of steel: Here, at times, it is difficult to get the chips that are being rapidly removed out of the way, and they stick in the flutes of a drill or pack around a cutting tool in such a way as to interfere greatly with the proper machining of the piece.

Let us take as an example a piece of steel which is being drilled on a horizontal turret lathe. Referring to Figure 131, the work, A, is held in a special collet chuck as shown in the illustration. The turret lathe in this case is provided with a system for lubricating the tool through a pipe, B, which connects with the turret as it is indexed from one position to the other. The drill, C, is of the "oil type," that is, it has a hole through the center and two ducts which lead out directly at the point of the drill through which the cutting lubricant is forced by means of the pump on the machine. As the pump forces the lubricant to the drill, the high pressure

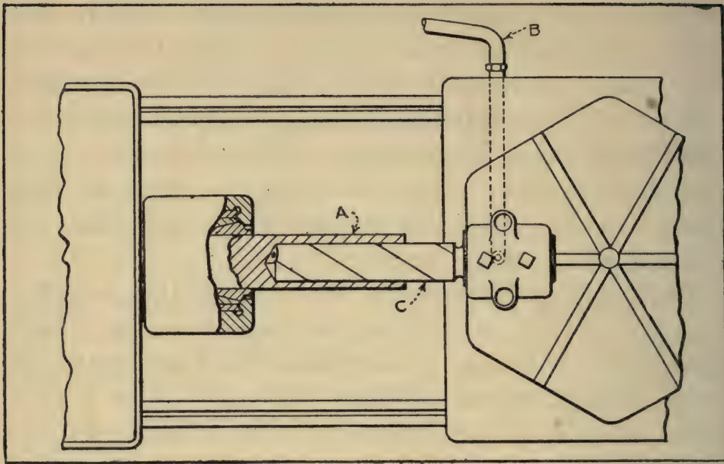


FIG. 131. INTERNAL OILING ARRANGEMENT FOR DRILLING ON A HORIZONTAL TURRET LATHE

of the fluid tends to force out the chips as they are generated by the end of the drill, along the flutes, so that eventually they find their way to the end of the work and drop out. A method of forcing lubricants through tools used on the turret lathe is not uncommon, although the practice varies somewhat with different manufacturers. Boring bars are not as easy to lubricate as some other forms of cutting tools.

Lubricating Through the Spindle of a Turret Lathe.—The device shown in Figure 132 was applied to a horizontal turret lathe in order to provide proper lubricating facilities for the cutting tools used in the inside work on the piece, A. The device was applied from the rear end of the spindle, but the pump used to force the lubricant to the spindle was a component

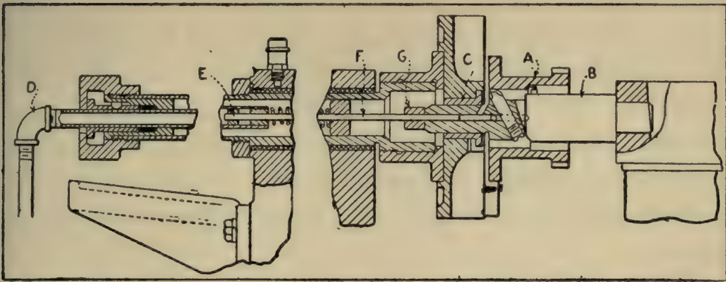


FIG. 132. LUBRICATION OF SPECIAL NATURE APPLIED TO A TURRET LATHE

part of the machine. A reference to the illustration will make it apparent that a boring bar, B, is used to bore two diameters on the inside of the work, and is piloted by a bushing, C, in the chuck.

In order to provide the inside cutting tools with proper lubrication, a pipe, D, is connected to the lubricant supply pump and is passed through the end of the spindle where it is guided in the packing bushings. Through the spindle and at the forward end, E, it is provided with a telescoping tube of smaller size, as shown at F. This smaller tube reaches forward and enters a hole in the end of the boring bar. From this hole other smaller holes lead out directly in front of the cutting tools. A coil spring takes care of the variations as the bar, B, progresses into the hole during the cutting action, and a stop collar, G, limits the forward movement of the tube, F, as it strikes against the end of the boring bar.

The application of a device of this kind to a turret lathe is not costly, and the results obtained by its

use are very satisfactory. At different times I have made a number of equipments for oiling tools through the spindle, most of which have been on a similar order to the one shown in this illustration. It is obvious that different conditions require slightly different methods of handling, but the principles involved in the design are much the same in all cases.

Flood Lubrication.—Nearly every machine of a manufacturing type is provided with lubricating devices of one kind or another, according to the type of machine and the nature of the work to be done. A turret lathe of the horizontal variety, for instance, is usually equipped with outside lubricating devices which will direct a copious supply of fluid against a piece of work that is being machined. A milling machine is also provided with an outside supply system for furnishing cutting lubricants to the cutters and the work, and flood lubrication (which means an excess supply of lubricants) is the usual method. The production of work from machines which are provided with flood lubrication for the cutting tools is far in advance of that obtained from machines of the older type which had an inadequate supply of lubricant.

In order to supply a machine with a proper amount of lubricant, or cutting fluid, and to direct the stream or streams to the proper position, it is necessary to arrange the piping in such a way that the spouts can be swung in any direction, longitudinally and vertically. By referring to Figure 133 an excellent example may be seen of the application of a cutting

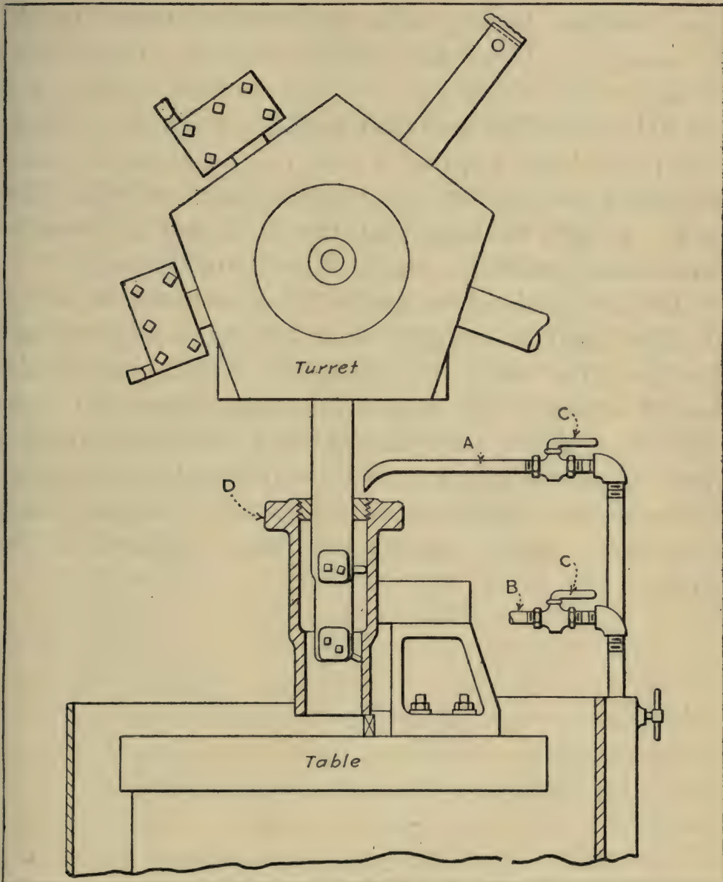


FIG. 133. CUTTING-LUBRICANT SYSTEM ON A BULLARD VERTICAL TURRET LATHE

lubricant system to a vertical turret lathe. This system is used by the Bullard Machine Tool Co. on their vertical boring mills and vertical turret lathes. A standpipe at one side of the machine contains two sliding tubes which can be adjusted vertically to suit the height of the piece that is being machined. These two tubes have spouts, A and B, and suitable cocks, as shown at C, to cut off the lubricant or reduce the flow. It will be seen that the fluid can be directed immediately onto the work, D, without difficulty.

One of the nice features of the device shown lies in the fact that the supply of lubricant is copious and can flood the work with a suitable cutting compound forced through the pipe by a pump located on the machine. After the cutting fluid has been used, it flows downwards and finds its way eventually through a fine screen back to the pump and is immediately sent forth again through the same channel to the work.

CHAPTER XX

CUTTING FEEDS AND SPEEDS

A Careful Study Required.—In order to obtain maximum efficiency from any machine tool it is an essential point that the proper cutting feeds and speeds should be used. The question then arises as to what cutting speed is correct for any given kind of material with a given feed. It is evident that a very little difference in the cutting speed and a slight variation in the feed used on a piece of work will make considerable difference in the number of pieces of work that may be produced in one hour, one day, or one year.

Let us suppose that a certain piece of work is being machined, and that the feed and speed are a little less than they should be. If it takes an operator ten minutes to produce a piece of work at the feed and speed that is being used, then a reduction of one minute in the time necessary to machine the piece would mean a considerable saving in total production time. In order, then, that the maximum production should be obtained from any machine, it is evident that the cutting feed and speed should be very carefully studied.

Definition of Cutting Speed.—The term "cutting speed in feet per minute" is not always thoroughly

understood by the non-technical man. In order therefore to make the matter more clearly evident to the reader a short explanation will suffice. Considered in elementary form, cutting speed means the number of feet of metal, considered as a continuous strip, which passes a given point upon the edge of a cutting tool in one minute. For example: Let it be supposed that I am planing a piece of cast iron 5 feet long, and that it takes me 10 seconds, or one-sixth of a minute, to make a cut the length of the work. It is evident that the cutting speed which I am using is 30 feet per minute, because it takes one-sixth of a minute for 5 feet to pass the cutting tool, and six-sixths of a minute will elapse while 30 feet of metal are passing the tool, not considering the return stroke of the planer.

In the same way a piece of cylindrical work which is revolving and passing a given point on the cutting tool, can be considered as a ribbon of metal unwinding from the outside of the work as fast as it passes the tool. In this case the circumference must be considered in determining the cutting speed. Let us assume that I have a piece of cast iron 20 inches in diameter which is running at a rate of 10 revolutions per minute, and I wish to know at what speed I am cutting the work, and whether it should be decreased or increased, and how much.

Formula for Determining Cutting Speeds.—It is evident that the circumference of the work, multiplied by the number of revolutions per minute at which it is running, and divided by 12 (which is the number of inches in one foot) should equal the

number of feet per minute at which the work is being cut. Or the solution of the problem would appear as follows:

$$\frac{20 \times 3.1416 \times 10}{12} = 52.4 \text{ ft. per min.}$$

As this process is a rather tedious one, let us take an approximation of the necessary figures, and from them derive a formula. If we take the constant, 3.1416, and divide it by 12, which is the number of inches to the foot, we obtain the figure 0.262, or, in round numbers, 0.250. Then by substituting this figure, 0.250 (or ¼), we obtain in place of the solution of the problem given above, another one:

$$20 \times 0.250 \times 10 = 20 \times \frac{10}{4} = 50$$

While this is not exactly correct, it is near enough for all practical purposes.

If we resolve the matter into a formula, then, we obtain the following:

$$D \times \frac{N}{4} = C$$

Where

D = diameter of work.
N = number of revolutions per minute.
C = cutting speed in feet per minute.

If we reverse this process in order to find the necessary number of revolutions per minute required for a piece of work of a given diameter to obtain a given cutting speed, we use the formula

$$\frac{4 \times C}{D} = N$$

Taking the same example as given above with the work diameter, $D = 20$; cutting speed desired, $C = 50$ feet per minute, then

$$\frac{4 \times 50}{20} = 10 \text{ r.p.m.}$$

It will be found that most of these formulas are very simple and can easily be memorized, so that all cutting speeds for any given diameter can be determined very rapidly by mental calculation.

The number of revolutions required to obtain cutting speeds for given diameters can be found in any mechanical handbook, but such a book is not always conveniently at hand when it is desired to know what a cutting speed is for a certain class of work. In such cases the above formulas will be found of great assistance.

Relation of Speed to Feed.—There are certain well-defined rules which can be applied to the correct setting of a feed and speed for a given piece of work when the composition and the quality of the work are known. An important factor in production work is the depth of the cut to be taken on the work. If a large amount of material is to be removed and if, therefore, the depth of the cut is considerable, it is evident that the amount of pressure brought to bear upon the tool and the amount of power required to pull the tool through the work are of first importance.

Speaking generally, the depth of the cut has a powerful effect on the feed which can be used and also on the speed. It would seem that there should

be, then, a direct relation between the cutting speed and the feed. That is to say, if a speed of fifty feet per minute were to be used and a feed of 1/32 of an inch per revolution of the work with a depth of cut of $\frac{1}{8}$ of an inch, it would appear logical that if the cutting speed were to be changed, the amount of feed would need to be changed also. Just how much change a variation of ten or fifteen per cent in the cutting speed would be required in the feed in order to produce the same results with the same amount of damage or injury to the tool, is a difficult question to decide.

However, the amount of stock to be removed from a casting or a forging is, in the majority of cases, very nearly uniform when the work is to be put through the shop on an interchangeable basis. We shall assume in our discussion of cutting feeds and speeds, then, that the amount of stock to be removed from any given piece of work is according to the usual practice. Speaking generally, the larger a piece of work is, the more stock is left to be removed by the cutting tool, because on large work, variations in the casting are more likely to be found.

On a piece of cast iron, six inches in diameter, the ordinary amount of finish left on the casting would not be apt to exceed $\frac{1}{8}$ of an inch on a side. On work 30 inches or more in diameter, there might easily be from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch of stock to be removed. It is very apparent, then, that in mamachining large work the depth of the cut would need to be deeper and, therefore, the feed would not be apt to be so great.

But there are other factors which enter into the machining of any piece, and these factors sometimes seem to contradict themselves. In the machining of a large casting, 30 inches or more in diameter, with a depth of cut 3/8 of an inch, it might be entirely possible to take a feed even a little greater than would be possible on a small piece six inches in diameter. The factors which would influence this matter are the power of the machine, the weight and rigidity of the work which is being machined, and the sectional area of the tool which is doing the work. The area of the tool would be proportionately greater on a heavy and large machine than on a small machine.

Conservative Cutting Speeds.—It will be noted from the foregoing statement that the amount of feed and speed which can be used on a given piece of work is not by any means an absolutely fixed amount. Given, however, a comparatively uniform amount of stock to remove from a casting of a known degree of hardness, there are certain conservative feeds and speeds which can be used with safety. It is always necessary in making an estimate of production on a given piece of work, to assume a certain cutting feed and speed which has been found by long experience to be within the limit of safety.

Assuming that the metals to be cut have been pickled or sand-blasted to remove any injurious scale that may be upon them prior to the machining operaton, and further assuming that the amount of stock to be removed is not excessive, the following table of cutting speeds for different materials

will be found to give results well within the limit of safety. It is always well in making an estimate of production on a given piece of work, to assume that the work is normal and not very hard, and that it has no excessive material to remove. Under these circumstances, after an estimate of production has been made, it is easily possible to speed up a machine slightly in order to gain a little in production, providing the material which is being cut proves to be of such a quality that it permits a little higher speed than normal.

Cast iron—50 feet per minute.
Cast steel—60 feet per minute.
Malleable iron—70 feet per minute.
Machine steel forgings (15 to 20 point carbon)—65 feet per minute.
Machine steel (black stock)—70 feet per minute.
Tool steel forgings—35 to 40 feet per minute.
Steel alloys (containing nickel and chromium)—30 to 50 feet per minute (depending on alloy).
Yellow brass—200 feet per minute.
Composition brass—120 to 150 feet per minute.
Bronzes—30 to 80 feet per minute (depending on alloy).

Importance of Proper Speeds and Feeds.—The importance of a correct cutting speed and feed cannot be overestimated. It is safe to say that the average manufacturer loses more money in the course of a year by incorrect setting of speeds and feeds in his factory than by any other single item in his total outlay.

A number of reasons are responsible for this, but probably the most usual one is the fact that no work-

man likes to grind tools. If a workman has a number of pieces of work to do on a machine which requires rather careful "setting up," he is quite apt to run his machine a little too slowly so that it will not be necessary for him to grind the tools very often.

It is the duty of any foreman of a department in a factory, to make sure that the production time on the work in process is as great as the nature of the work will permit. It is furthermore the duty of the progressive executive to make certain in his own factory that he is obtaining the results that he should obtain by making a personal examination of the methods in use from time to time, and to keep himself posted in regard to the work, so that productive inefficiency shall not be laid to a lack of knowledge on his part.

Allowance for Exceptional Cases.—While it is all very nice for a tool engineer, an executive, or a foreman in a factory to determine positively beforehand exactly at what speed any piece of work must be run, it is an entirely different proposition to tell the man in the factory who is doing the work that he must run that work at exactly the prescribed speed and feed. Getting back to first principles, it would be entirely possible to fix absolutely every cutting speed and feed in the factory, providing the material which was being cut were exactly of the same quality in each and every case. Unfortunately, however, foundry practice is not such as to give absolutely certain results. Sometimes a group of castings will be found very hard, while in other cases they will

be soft. It is evident that the first group cannot be machined as rapidly as the second.

In these days of rapid production and high speed, it frequently happens that several patterns are made of the same piece of work, and in order to obtain the castings as rapidly as possible, the patterns are sent to different foundries. Invariably the castings from one foundry will differ in some respect from those of another foundry, and due allowance in setting speeds and feeds must be made for such conditions. So also in the case of alloy steels, a very great difference may be found in two lots of forgings, although in this case the trouble is not caused by the composition as a general rule, but is more likely to be the result of an improper treatment of the forgings after they have been made.

The remedy for conditions of this kind is apparent. It is certainly not the part of economy for the manufacturer to reduce his production speed just because a foundryman or a drop-forge department has made errors, or has neglected to do some of the things that should have been done before the castings or forgings were delivered. However, it may happen that the manufacturer does not feel disposed to send back a lot of imperfect or improperly treated castings or forgings, and prefers to machine them as they are. In such a case he will have to establish arbitrary machining speeds, and his decisions must be governed by the conditions.

Effect of Lubricant on Feed and Speed.—In the previous chapter the matter of cutting lubricants was discussed and various data were given in regard

to the most suitable lubricant for various classes of materials. In tool-room work, however, it is very often the case that the workman does not wish to use a lubricant in cutting a piece of metal. This is largely because the use of a lubricant results in much dirtier work, which is difficult to handle. Hence, the toolmaker prefers to cut his work dry as a general thing. There is no particular reason why a workman on this class of work should not use his own judgment as to lubricants. He might be able to produce some classes of work more rapidly by using them, because he could use a little higher speed and a little more feed, but in the long run no particular gain would be found. Of course, in making heavy roughing cuts in the tool room, or anywhere else in the factory, a lubricant will undoubtedly be found of great advantage. In the table given previously in this chapter, it is assumed that a proper lubricant is to be used on work which needs lubrication.

General Rules.—Speaking generally, the amount of feed and speed to be used for any work produced in quantities, should be as great as the work will permit without obliging the workman to re-grind his tool more than three times in one day. Naturally, there are exceptions to this rule, but as a general thing if the workman is not obliged to grind his tool oftener than once a day, he is losing time in production. But, on the other hand, if the workman finds it necessary to re-grind his tool about once every hour, it is a sure indication that the speed is too rapid or the feed is too deep.

I recall a rather peculiar incident connected with the use of the proper cutting speed and feed that happened some years ago. In passing through a factory, a workman stopped me and asked if I could tell him what kind of steel he could use in place of the tool he then had. On questioning the man it appeared that he was grinding the tool after he had produced about two pieces, and this tool grinding kept him busy for some minutes each time. On examining the work, I found it to be a piece of bronze about 4 inches in diameter. The workman proceeded to cut one of the pieces while I was standing by his side. I noticed that the speed seemed to be excessive, and by counting the number of revolutions per minute, I saw that he was running the work at something over 600 feet per minute. As the work was a piece of manganese bronze, it is evident that the tool was being ruined about as fast as he could re-grind it. After he had reduced the speed to about 100 feet per minute he had no further difficulty with the tool. This example simply illustrates conditions which sometimes obtain in a factory on account of the ignorance or carelessness of the worker.

As it is absolutely impossible to set a cutting speed or feed for a piece of work without making a trial to see whether the work is hard or soft, it behooves every factory manager or executive to see that the greatest care is used in making these determinations. After the speeds and feeds have been set as nearly correct as possible, it is well to make an examination to prove that the results show that the work is being produced to the best advantage. The foreman should

test the various machines from time to time in order to make sure that the maximum efficiency is being obtained. For, next to proper cutting tools, speeds and feeds are of first importance. In order, then, to see that the factory is obtaining the maximum output, all these various points must be considered, and each one must be planned in such a way that there will be no loss either from incorrect handling, from improper setting of tools, or from incorrect speeds and feeds. When all these matters have been looked into by the proper men, the executive can feel assured that he is obtaining the full capacity of the machine, and when he has done this he has approached closely to maximum efficiency.

CHAPTER XXI

PLANNING AND LAYING OUT WORK

Business Aspects of Planning.—If a man were about to build a house, his first step would be to determine what kind of house he wanted. He would devote considerable time in sketching out certain arrangements of rooms, and after he had determined about how many rooms he wanted and how much he wanted to pay for the house, he would take his sketches to an architect who would draw up a set of plans from them. After the architect had planned the house carefully, he would make an estimate on the cost of the various building operations. That is to say, he would estimate the amount of excavation required for cellar and foundations and the cost of all other matters connected with the actual building. He would then submit his plans to a number of carpenters and builders and obtain bids from them.*

At least, this is the procedure that would be followed by the average man; but here and there one will find a peculiarly constituted individual who, quite probably, would take his rough ideas to a carpenter and say, "Here are some ideas of a house I want built. Go ahead and build it like that." The resulting house can readily be imagined.

* Full discussion of the mechanism of planning will be found in Planning and Time Study, by G. S. Armstrong, Factory Management Course.

In any kind of business venture involving the outlay of a number of dollars, a business man would be sure to investigate thoroughly all matters connected with the project. In fact, in any buying or selling proposition, the man whose money was to be used would be apt to look up every point in connection with the spending of his money. So also in the manufacture of any kind of product, it is of the first importance to study the methods of production that are to be used and to plan carefully in advance all of the operations necessary to complete the various parts for the finished product.

The importance, then, of the planning department in manufacturing can readily be seen. It would certainly be the height of folly for any manufacturer to go ahead and obtain a great number of castings, forgings and other material from which the various parts were to be manufactured, and then, without further thought about the matter, to put these parts out into his factory without any particular plan or scheme of operation in his mind. And yet in many cases, especially in old-established factories, the matter of planning and laying out the various operations for any given piece of work is almost entirely neglected. It is true that the operating official, in cases of this kind, depends largely upon his foreman and workmen to step into the breach and produce a finished piece of work which resembles the mechanism which he is attempting to build. In the progressive factory, however, the planning department receives the most careful attention, and the men who are at the head of it are specially trained. In addition, their

long experience enables them to plan in advance every detail of the work to be done. In no other way can the greatest efficiency be obtained from any factory, and although the outlay necessary for a well organized planning department is fairly large, the results obtained more than offset the expenditure.

One of the best examples of careful planning can be found in the Ford Motor Company plant in Detroit. Were it not for the care and forethought which has been used throughout this factory, it would have been impossible to obtain the tremendous production of these Ford cars.

Tool Engineering Methods.—The importance of tool engineering has only recently been brought to the attention of the manufacturer. A few years ago the tool designer in a factory was supposed to lay out the various operations on the work which was to be done, but this laying out of operations was in the main a rather unfinished procedure. It is true that the old-fashioned tool designer would make a rough layout of operations necessary to complete a certain piece of work, but he would not go into the matter very thoroughly. The method used by the modern tool engineer, however, is such that every point in the manufacture is taken up with the greatest care and nothing is left to chance. All the operations which are to be done on the work are simply planned in accordance with the equipment of the factory. More than this, the equipment (if it is insufficient to do the work required) is added to, in order that maximum efficiency on the work in process may be obtained.

The matter of planning is of such great importance that I intend to take it up in this book in considerable detail. I believe that the best way to describe the methods used and the processes which are applied by the tool engineer, is to describe the various steps which are taken. In order that the subject may be as clear as possible, let us assume that a modern factory, very well equipped with machine tools of good design—one which has been used for automobile work—is about to proceed with the manufacture of a new model, and that the drawings of the complete mechanism have been handed over to the tool engineer ready for him to design the tools and fixtures for the work which is to be done. Let us also assume that the tool engineer has been employed by the same company for several years, so that he is thoroughly familiar with the machine tool equipment.

Let us follow the steps taken by the tool engineer in this work, noting the various points of importance, which will be discussed at length later in this chapter. Let us assume, then, that the tool engineer has a pile of blue-prints on his desk—he picks up one of the important pieces (usually one of good size and considerable importance), and takes up the points logically about as follows:

1.—Looks over each blue-print, compares it with the assembly drawing, and notes the important fits, the relation of the piece in question to the other parts of the mechanism, and so on.

2.—Makes rough notes of the various operations necessary for the completion of the work.

3.—Looks over the machine-tool equipment of the

factory, to see what machines are best adapted to produce the work necessary.

4.—Determines the jigs and fixtures needed in the work of production, notes gauges necessary, and also the accuracy required for the various fits.

5.—Lays out the operation sheet in detail.

6.—Makes rough pencil sketches of jigs, fixtures and other tools necessary in the production.

7.—Makes layout sheets.

8.—Makes time-studies from layout sheets.

9.—Designs jigs, fixtures, and special tools, together with gauges needed for the work.

10.—Notes number of machines required, determined by the time-studies made for the various operations.

11.—Turns over the time-study sheets to the cost department, in order that piece-work prices may be set from the estimated time of production.

Now these various steps which are taken by the tool engineer are not all undertaken at once, but approximately in the sequence just given, although the practical engineer is often able to combine several at a time. Let us now take up each of the points in detail.

1: **Preliminary Processes.**—Now in the first step which the tool engineer takes, he makes a rather rough analysis of the work which is to be done, but he does try, in this preliminary inspection, to grasp the important details of the construction and obtain a very good general idea of what lies before him. In addition to this, he familiarizes himself with the general

points in the construction of the mechanism which he is to build, by an inspection of the assembly drawings. He studies these assembly drawings carefully, in order to learn the general construction of the entire mechanism of which the piece shown on the blueprint that he is examining, is a component part. He notes very carefully whether certain of the parts should be a tight fit, or whether they should be a sliding or a running fit, and he determines the importance of their relation to the entire mechanism. After the tool engineer has gone over a few pieces of work in this way, he begins to form a very good idea of the work which he is about to do. He is now ready for the second step in the process.

2: Preliminary Layout of Operation.—Taking up the piece now in detail, the tool engineer roughly plans the operations which are necessary for the completion of the work, and makes notes in pencil in the form of a memorandum, by which he is guided when he makes the more serious, careful planning. For example, he makes a note to this effect on his memorandum pad: "This piece must be chucked, the hub must be turned, and the inside must be bored out on a turret lathe. The other end of the work also must be finished and turned, requiring another screw-machine or a turret-lathe operation. There are to be six drilled holes around the flange of the piece, and these must be bored in a drill jig on a multiple-spindle drilling machine. There are also several other operations of milling and counterboring, and perhaps even one or two besides these." In any event, the tool engineer's memorandum on this work will

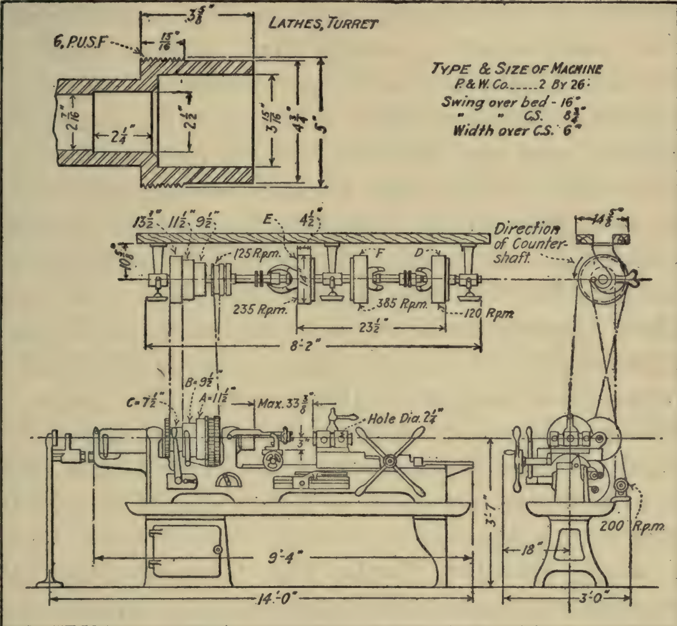
cover everything which is to be done to the piece, but it may be that the operations, as noted by him, may not be in the sequence to produce the piece to the best advantage. This matter will be taken up later as the careful layout of operations is made.

3: Machine-Tool Equipment.—Now it must be understood that although the points mentioned are given in sequence, in reality often, as I have said, many of these points are taken up by the tool engineer at the same time, since he is trained to this kind of work, and therefore when he thinks of a piece of work or an operation which is to be done on a given piece of work, his mind automatically selects the type of machine which, in his estimation, is most suited to the work in hand. He also is possessed of a knowledge of the various machine tools which the factory has on hand, and knows something about their condition and their adaptability to certain classes of work. It is obvious, however, that in a large factory the tool engineer cannot carry all of these details in his mind, so that it is necessary for him to have a complete record of the machine tools contained in the factory.

This matter brings us to the point of a reference machine-tool index, which every progressive tool engineer must have. The amount of detail contained in a record of this kind is governed by the size of the factory and the kind of product which is being manufactured. It is evident that in a small factory it would be comparatively unnecessary to have a detailed record of every machine tool in the shop, with its feeds, speeds, and other data regarding its capa-

city. But it will be found that in a large factory details of this kind are of the greatest importance. For work of this sort, then, the progressive engineer in a large factory endeavors to make his index of machine tools as complete as possible. I have found in my own work of tool engineering, that a large card with an outline of the machine tools upon it, in at least two views, and with various data concerning feeds, speeds, and capacity, is of the greatest value. I believe that a card is much better than a loose-leaf book, because the card can be taken out of the file and used as a reference by the tool designer without disturbing other data which may apply to other machines.

Perhaps a still better scheme would be to have the data on the various machines drawn up in such form that it can be blue-printed. It is apparent that if a blue-print were to be made there would be little danger of any cards getting lost and of the consequent large amount of labor to accumulate the information once more. An example of a machine-tool record record card which I have found of great value, is shown in Figure 134. It will be seen that this card is very complete with respect to the data needed by a tool engineer to determine whether or not a certain type of machine is suited to the work in hand. If this kind of information is lacking, it is necessary, in designing a set of tools for any given machine, to have the tool designer or a draftsman go into the shop and make certain measurements on the machine itself, or else obtain what meager information he can from a catalogue.



SPEEDS IN REVOLUTIONS PER MINUTE									
	D			E			F		
	A	B	C	A	B	C	A	B	C
SLOW BACK GEARS	15	21	30	28	41	60	45	67	99
FAST BACK GEARS	44	56	83	75	111	164	124	183	269
OPEN BELT	114	145	213	194	285	423	319	466	692

FEEDS IN INCH PER REVOLUTION								
	TURRET SLIDE				CROSS SLIDE			
FEEDS	0.007	0.011	0.015	0.020	0.0012	0.002	0.0028	0.0035

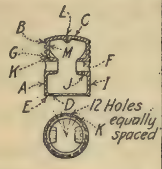
FIG. 134. MACHINE TOOL RECORD CARD FOR A TURRET LATHE

Now, assuming that our tool engineer is well equipped with data of this kind, he can very easily look over the work which is to be done and determine which machine of a certain class is best suited to the work. He may be aided in this selection by a knowledge of the way in which a piece of similar character was machined at some previous time, but whether this is the case or not, new machine tools may have been added since that time which are more adaptable to the work. In this case it is natural to assume that the tool engineer will select the more modern type of machine. Another point which must be considered in the same connection, is the location of any given machine in the factory. The matter of handling a piece and taking it from one department to another and then back again, entails an extra cost of handling the work, and this should be avoided as far as possible.

4: Jigs, Fixtures, Tools, and Gauges.—Now, the tool engineer has reached the point in his analysis at which he is ready to take the fourth step. The engineer then looks over the blue-prints carefully, and notes on his memorandum sheet that he needs the following tools: a drill jig, for drilling a certain series of holes; a milling fixture, for milling a certain part of the work; and some turret lathe fixtures, for operations of a cylindrical character, such as boring or turning of the work. He may also decide that some particular piece of work can be handled to advantage on an engine lathe, or, if it is large, on a vertical boring mill. When the engineer looks over these pieces he does not stop to consider design,

but simply decides that he needs one jig or two jigs and one or two milling fixtures, and perhaps a turret lathe faceplate, or special sub-jaws, or some other types of fixtures. At this time, also, the matter of gauging is considered, and a memorandum is made as to the types of gauges needed—whether they are to be plug, ring, snap, or indicating. Also, whether the work is to be gauged from some of the rough surfaces in order to make sure that a proper amount of finish is left for some subsequent operation, or to make sure that there is a clearance between some finished portion of another part and a rough portion of the work in hand. In connection with this phase, he must frequently refer to the assembly drawing of the mechanism in order to make sure that all these points have been considered. Having gone to this point in the analysis, the tool engineer is now ready to go into the matter of the operations on the work in detail.

5: **Laying Out Operation Sheets.**—In connection with the preliminary work mentioned, this fifth step represents the most important of all the work done by the tool engineer. One of the peculiar things about the average manufacturer is that when he sees an operation sheet completely and properly made out, he does not realize for an instant the amount of work necessary to produce a result such as that which appears on the operation sheet. He sees, for example, a sheet perhaps 10 x 12 inches in size, on which is a list of the operations and the tool called for, and everything appears to him to be as simple as a, b, c. If, however, the executive, in considering the work



BLANK MOTOR CAR COMPANY
TOOL AND OPERATION SHEET

NOTE: THIS OPERATION SHEET NOT TO BE CHANGED WITHOUT WRITTEN INSTRUCTIONS FROM ENGINEER

PIECE No. 166
NAME Piston
No. OF PIECES PER UNIT 4
MATERIAL C.I.
ALLOY —

PRODUCTION						EQUIPMENT						REMARKS
OPER No.	LAYOUT SHEET	METHOD OF LOCATING AND HOLDING	DESCRIPTION OF OPERATION	TYPE OF MACHINE	DEP'T.	TOOLS JIGS OR FIXTURES	DWG. No.	GAGES	DWG. No.	ESTIMATE HRLY PROD PER MO.	No. OF MACH REQ'D	
1	L-79		Clean Casting	Sand Blast	Foundry							
2	L-79	Hold on inner surface "M" on 6 Pins in pin Chuck stopping against inside of closed end	Rough Turn O.D. "A" Rough form Surface "C"	Potter & Johnson 2-P. Piston Machine	Lathe	Expanding Pin Chuck Turning Tools Radius Tool-Cross slide Tools	1020	Snap 106.5: 105.7	G-114	16	30	
3	L-79	Hold in Soft Jaws on surface "B" stopping against radius end "C"	Bore & Ream open end "D"-96 m/m and Face end "E"	Warner & Swasey Tur. Lathe #2-H.	Lathe	3 Jaw Gear Scroll Chuck; Special Soft Jaws; 2-Cutter Bar (Special); 1-Reamer (Floating Holder); Note:- Bonds spring [illegible])	1121; 1009	Gage 96 $^{+.0025}_{-.0012}$; Depth Gage	G-115; G-116	30	16	Order ext. Jaws from Warner & Swasey
4	L-79	Location on "D" with Adjustable V. Blocks on inner Bosses & Clamp against "C"	Rough Drill Wrist Pin Hole "F" 20 m/m	Barnes 20" Dr. Press	Drilling	Drill Jig - Drill	833	No Gages		20	25	
5	L-79	Set on end "E" in Furnace	Season Casting	Annealing Furnace	Heat Treat.							450° to 500° Fahr.
6	L-79	Locate on "D" & "E"	Drill center hole "L"	Sens. Dr. Press	Drilling	Special Dr. Jig & Center Drill		Size Block 7 m/m	G-117	45	10	Use Stop Col. for Depth
7	L-80	Location "D" & "E" with Draw back rod pin in "F"	Finish "A" Rough finish "B" form end "C"	Warner & Swasey #4 Univ. T. L.	Lathe	Spec. Arbor Spec. Tools for Grooves etc.	1375 to 79	for Grooves; Snap $\frac{105.25}{106.15}$	G-118	6	75	
8	L-80	Locate same as Oper. 4	Bore & Ream Wrist Pin Hole	Colburn Dr. Press	Drilling	Spec. Fix. Bars and Reamer - 22 - .003	836	Plug 22 $^{-.075}_{-.100}$	G-119	12	30	Leave $^{.003}_{.004}$ for Hand Ream
9	L-80	Locate from Hole "F"	Drill & Ream "J"	Sens. Dr. Press	Drilling	Dr. Jig - 59 Dr. 60 Reamer				45	10	
9-a	L-80	Locate same as in Oper. 4 with Draw back pin	Dr. (12) 1.5 m/m holes at angle	8 Spindle Press		Index Jig Drill 1.5 m/m	842			75	20	
10	L-80	Use arbor similar to oper. 4	Grind "A" & "B"	Norton Grinder 10 x 36	Grinding	Plug Arbor	978	Snap 104.7 $^{+.0005}$ - 104.9 $^{+.0025}$	G-120	10	50	
11	L-80	Grip by Wooden Blocks on "A" in Vise	Hand Ream Holes "F"	Bench		Reamer 22.00 m/m	1292	Plug 22.00 $^{+.012}_{-.006}$	G-121	60		
12	L-80		Inspect	Bench	Inspection			Complete Gages alignment of Wrist Pin	G-122 to 125			

FIG. 135. TOOL AND OPERATION SHEET ON A CAST-IRON PISTON—FOUR PIECES PER UNIT

of the tool engineer in this respect, were to stop for a moment and think that every word written on the sheet represents the most careful thought, and that only as a result of a number of years of hard experience has the tool engineer acquired the knowledge and skill necessary in the laying out of an operation sheet—then the executive would acquire a more wholesome respect for the tool engineer and for his work. It is only recently, as I have said, that the executive has been able to see the value of preliminary planning as carried out and brought to completion by the experienced tool engineer. Therefore, to the executive who has not reached this point, and who still seems to consider that this work is more or less of a "cut and dried" proposition, I would recommend that he reconsider his attitude in this regard and give the tool engineer the credit to which he is entitled.

In the first place, an operation sheet in itself should be made in such form that it gives all the information necessary in regard to the tool equipment and the machines necessary to do the work. I have laid out a number of operation sheets for different firms and on various classes of work, and I have found that a sheet similar to the one illustrated in Figure 135 is about as complete as anything of this kind can be made if the sheet is to be of a size to allow of binding in a loose-leaf holder, for ready reference. The form indicated is preferably about 14 x 17 inches in size, but it can be made a trifle smaller if desired. It is bad practice, however, to endeavor to make a sheet of this kind very

small, as the necessary information cannot be included on a sheet of much smaller size than that just mentioned. Referring to the sheet shown in the illustration, the reader will see that the data contained on it is complete to the smallest detail. At the upper left hand corner a small scale drawing of the piece appears, in order that a reference to the various operations may be made by means of letters, as indicated. Generally the drawing of the piece can be made about one-quarter scale, but on very large work it may be advisable to leave a larger space for the outline drawing. This matter is largely determined by the class of work which is to be done. I believe that the form shown gives every essential detail in regard to any piece of work which is to be manufactured, and forms a complete record which can be referred to at a moment's notice. If desired, the operation sheet can be printed on tracing paper, and afterward blue-printed so that any number of record proofs can be made.

It will be seen that a reference to a sheet of this kind will give the executive or the tool engineer all the information which he needs, from the process used in manufacturing the product, down to and including the type of gauge needed and the drawing number of the gauge, or of the tool, jig, or fixture. In addition to this, the estimated hourly production per machine is given in the "Remarks" column, and the number of machines which are required for whatever production may be determined upon beforehand. The "Remarks" column also has a little additional space, which can be used for any data

in addition to that for which space is provided in the tabulated list.

After the tool engineer has gone into the matter of machining the work, and has laid out the operations, the tool designers use these sheets to work from, and as fast as the drawing numbers have been obtained from the clerk, they are entered up in their proper place against the tool or fixture which they represent—so that before very long, the record is complete. When this point has been reached, the sheet should be either blue-printed or copied, and an original should be filed away in a record book, from which no sheet must ever be taken for any purpose whatsoever. If it is found necesary at any time, during the progress of the work, to make a change in the method of handling, a record of the change which is to be made should be filed in a separate book devoted entirely to this purpose. A statement of the reasons for the change should be embodied in the record, and the authority for making the change must also be given. It is not an uncommon thing for an operation sheet for a difficult piece of work—like a crank case for an automobile, or a receiver for a military rifle—to be worth several hundred dolars in actual labor expended on the planning of the operations shown on the sheet. It is therefore evident that it behooves any factory executive to see that the greatest care is taken in regard to these points.

In laying out the operation, the tool engineer goes into every detail of manufacture carefully, as will be seen if the illustration is referred to. At the

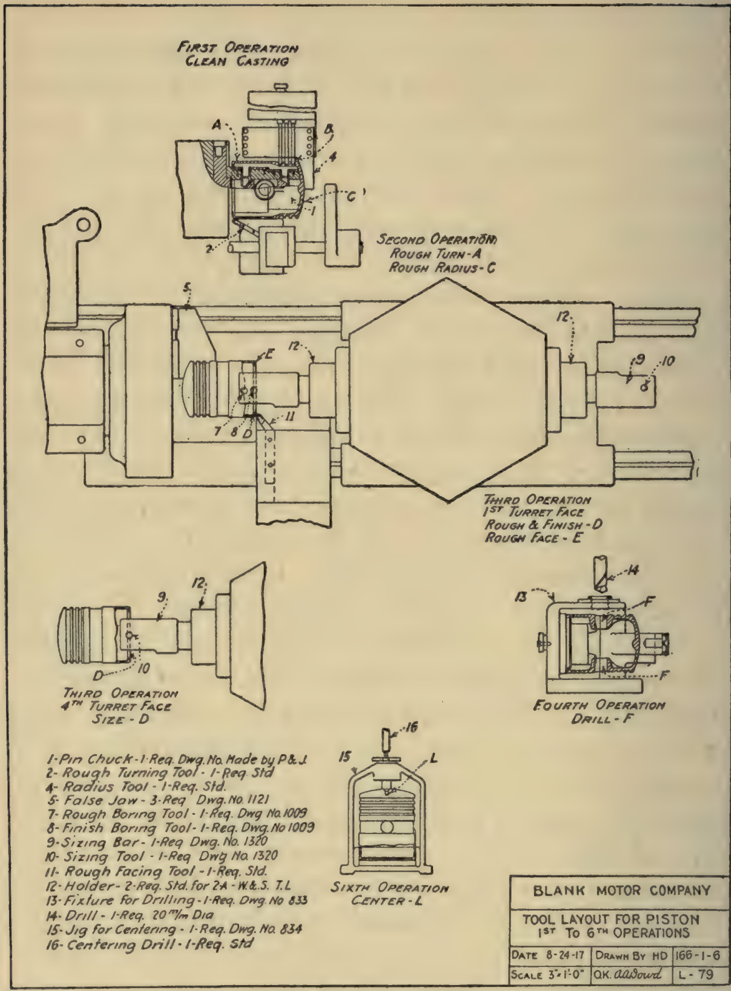


FIG. 136. TOOL LAYOUT SHEET FOR PISTON—OPERATIONS 1 TO 6

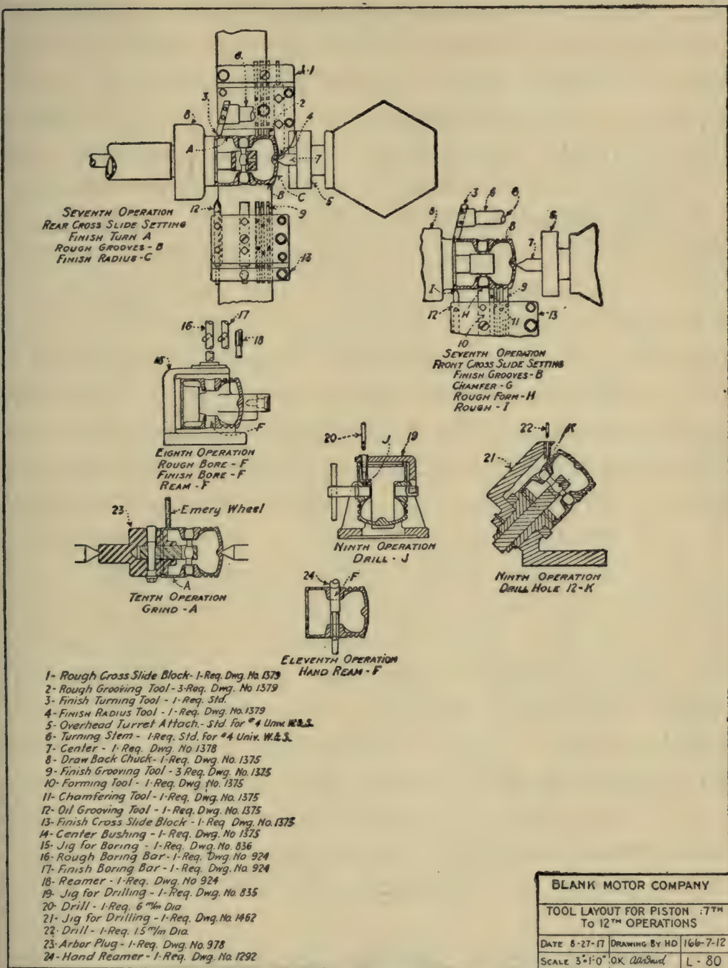


FIG. 137. TOOL LAYOUT SHEET FOR PISTON—OPERATIONS 7 TO 12

same time, however, he takes up points in connection with the manufacture, and makes sketches to give the tool designer his ideas concerning the fixtures which must be made. These points are mentioned in connection with the sixth point, following, but really the sketches are made directly in connection with the laying out of the operation sheet.

6: **Free-Hand Sketches.**—The matter of making a sketch, preliminary to the designing of a tool or fixture, is of considerable importance, and the progressive tool engineer is systematic in this as in other respects. Therefore, when he makes a sketch for a piece of work, he does one of two things: he either makes the sketch on a loose-leaf pad and binds the sketch in a book kept for that purpose, in numerical order according to the piece number assigned to the work; or he attaches a sheet of sketches to the operation sheet. This latter method is not good, for the reason that these sheets can be easily lost, and may never be found. In which event, the tool engineer's ideas may, or may not, be followed—there is no proof, in either case. It is a very simple matter to have a number of books, or even a note-book of plain paper, in which sketches can be kept The loose-leaf system, however, is much to be preferred, since, when that is used, the arrangement of the pieces in numerical order can be more easily kept.

7: **Making Layout Sheets.**—The making of the layout sheets may be considered by the executive as a costly and unnecessary proposition, yet it will be found that in the long run the preparation of these

sheets will save much time and expense. A layout sheet like that shown in Figures 136 and 137 is a picture of the various methods used in handling the work. The tools which are to be used in the work are indicated and are given a number, and anything of a special nature in the line of equipment is shown in sufficient detail to make the method used perfectly clear. These tool-layout sheets either may be made in connection with the tools, jigs, and fixtures which are being drawn up, or they may be made in advance. If made in advance of the actual designing of the tools, it is necessary that the work should be done by a man of wide experience—one who possesses the knack of sketching out an idea rapidly. Layout sheets of this kind are usually made one-quarter size, and the sheets may be so proportioned that they can be reproduced by a photostatic process and kept as a record with the operation sheets; or they may be bound in a separate book and kept for record. It will be noted, with respect to the sheets shown in Figures 136 and 137, that a complete record of tools used in the various operations is given at the bottom of each sheet, and that the drawing numbers used on each jig, fixture, or tool are specified in connection with this work.

It is unnecessary, in making a layout sheet, to go into the smallest detail in regard to the design, but an effort should be made to represent a fixture which can be readily understood, and which will contain sufficient detail to show the methods used. One of the greatest advantages in a tool-layout sheet is in connection with turret-lathe operations. In the set-

ting up of a turret lathe there are cases when an interference appears, and, unless a layout of some kind is made, this interference may not be noticed until the work is set up in the factory and the operator is ready to begin the work. When an interference is not discovered until as late as this, it may cause a delay of several days in the production, and this delay may be a costly one to the manufacturer. Looking at the matter from all standpoints, I believe that for work requiring a number of different operations, and for pieces of unusual character, the use of a layout sheet is of great value. For small work which does not require anything elaborate in the line of special tooling, it may not be necessary to make such a layout, but even in cases of this kind the amount of labor involved is offset by the advantages gained.

8: **Time-Study Sheets.**—There are two ways to make a time-study. One of these is to estimate the amount of time necessary to produce the work at certain speeds and feeds; the other is to take the actual time of the work in the factory. In the first instance, the man who makes the time-study must be a man of broad experience who is familiar with all kinds of machine tools, and one who has access to the tables giving the the speeds and feeds of which various machines in the shop are capable. In the second case, it is unnecessary to have a man of very wide experience, because he simply watches the work of the man in the factory and notes the amount of time taken for doing a certain piece of work.

TIME STUDY SHEET BLANK MOTOR CAR CO. DETROIT, MICHIGAN.										PIECE NO. *166* NAME *Piston* MAT. *C.I.*	
OPN. NO.	DESCRIPTION OF OPERATION	TYPE OF MACHINE	CUTTING SPEED FT. PER MIN.	DIAM. OF WORK	LENGTH OF WORK	WIDTH OF SURFACE	R.P.M. OR STROKES	FEED PER REV. OR STROKES	CUTTING TIME MIN.	ALLOWANCE MIN.	TOTAL
2	Rough Turn A	*2 P.P.&J	50	105 m/m	130	-	48	0.040	$2\frac{1}{2}$	$2\frac{1}{4}$	
	Rough Radius C	"	"	+	+	+	"				
	Allow for set up and removing work									$\frac{3}{4}$	$3\frac{1}{2}$
3	R.&F. Bore (D)	*2A W.&S.	50	96 m/m	15 m/m	-	48	0.040	$\frac{1}{4}$	$\frac{3}{8}$	
	*Size (D)	"	"	"	5	-	48	0.040	$\frac{1}{8}$	$\frac{1}{4}$	
	Face (E) (C.S)	+	+	+	+	+	+	+	+	+	
	Allow for set up and removing work, indexing etc.									$\frac{7}{8}$	$1\frac{1}{2}$
4	Drill Hole F	20" D.P.	50	20 m/m	58 m/m	-	250	0.005	$1\frac{3}{4}$	2	
	Allow for set up and removing work, cleaning jig etc.									1	3
6	Center End (C)	Sens Dr.	60	10 m/m	12 m/m	-	500	Hand	$\frac{1}{4}$	$\frac{1}{2}$	
	and countersink										
	Allow for set up and removing work, cleaning jig etc.										
7	Finish Turn (A)	*4 W.&S.	50	105 m/m	130 m/m	-	48	0.040	$2\frac{1}{2}$	$2\frac{3}{4}$	
	Rough Grooved (B)	"	40	"	6 m/m	-	38	0.006	1	$1\frac{1}{4}$	
	Finish " (B)	"	30	"	6 m/m	-	28	0.006	$1\frac{1}{2}$"	$1\frac{3}{4}$	
	Form Rad. (C)	"	30	"	2 m/m	-	28	Hand	$\frac{1}{2}$	$\frac{3}{4}$	
	Allow for setting and removing, indexing and gaging									2	$8\frac{1}{2}$
8	Rough Bore (F)	Colburn	50	22 m/m	58 m/m	-	250	0.010	1	$1\frac{1}{4}$	
	Finish Bore (F)	"	50	"	"	-	"	"	1	$1\frac{1}{4}$	
	Ream (F)	"	30	"	"	-	150	Hand	$\frac{1}{4}$	$\frac{1}{2}$	
	Allow for removing and inserting tools and work									2	5
9	Drill (J)	Sens Dr.	50	6 m/m	6 m/m	-	800	Hand	$\frac{1}{4}$	$\frac{1}{2}$	
	Allow for removing and inserting work									$\frac{3}{4}$	$1\frac{1}{4}$
9A	Drill 12 Holes (K)	Sens Dr.	60	1.5 m/m	6 x 12	-	4000	Hand	$1\frac{1}{4}$	$1\frac{1}{2}$	
	Allow for indexing, setting and removing									$1\frac{1}{2}$	3
10	Grind O.D. (A)	Norton	4000	Wheel 18"	130	-	900	0.0005 0.0001	5	$5\frac{1}{4}$	
	Allow for setting and removing work, gaging etc.									$\frac{3}{4}$	6
11	Hand Ream (F)	Bench	-	-	-	-	-	Hand	-	-	$1\frac{1}{2}$

FIG. 138. TIME-STUDY SHEET ON A CAST-IRON PISTON

It is entirely possible for an experienced man to determine very closely the amount of time which will be required for the performance of a given operation on any piece of work. His experience will tell him approximately what feed and speed can be safely used on the work, and as he can easily ascertain the length of the surface which he is about to cut, the time can be quickly estimated. A very good illustration of a time-study sheet is shown in Figure 138; it will be noted that various columns are provided for the different data used in connection with the estimates. The time-study sheet itself is self-explanatory.

Now let us take up the method of figuring—or perhaps we should say estimating—the amount of time for a given piece of work, as indicated by the layout sheet. If the tool engineer is about to figure the time necessary on the work, his first step is to determine the rate and settle the matter of cost of the tool. The best method of holding the work must always be determined, and also the points from which the piece is to be located. Other matters in connection with the design of tools and fixtures have been taken up in the previous chapters.

9: Machine Tools Required.—After the time-study sheet, mentioned previously, has been made, the amount of time necessary with each machine can be easily determined, and in order to make sure that a sufficient number of machine tools are at hand to give the production necessary, and within the proper time, a record must be kept to show how many pieces are to be handled by any one type of machine,

and how much of this machine time will be needed. The best way to determine whether the requisite number of machines is available, is to make a tabulated list of the various machines in the factory, and after the time-study sheet has been made, the amount of time which each piece consumes on a given type of machine can be tabulated in the list mentioned. In this way, as the work of the tool engineer progresses, it is very easy to see when any one machine or type of machine is overloaded. Then, when it is found that a certain type of machine has more of a burden than it can reasonably be expected to sustain, some of the work which has been placed upon it can be transferred to some other type of machine adapted to the work. By using a process of this kind, and by carrying all these matters along together, the matter of distribution of the work in the factory can be adjusted to the best advantage. The last point can now be taken up by the tool engineer.

10: Setting Piece-Work Prices.—The matter of setting piece-work prices does not strictly come under the head of the tool engineer's work—the time-study sheet for the various operations on each piece of work is used by the cost department in obtaining a basis upon which to figure the cost of production. If the work on the time-study sheet has been carefully done, the piece-work prices can be determined with great accuracy by the cost department, and the prices so set will be found to give excellent results. If, after a test has been made of the production time as indicated by the time-study sheet, there is found

to be a considerable difference in time, then the matter should be immediately referred to the tool engineer for his attention. If it should be found that an error has been made in his estimate of production, then the piece-work price may be changed to allow for the error On the other hand, if it is found that the workman is really consuming too much time in doing the work, the matter of speeds and feeds which he is using should be carefully looked into, in order that the source of the trouble may be determined.

Often I have found that the only reason why the production time did not check with the time-study, was that the operator was not using the speeds and feeds which would produce the best results. There are, of course, exceptional cases in which the work is of such a nature that the speeds and feeds which have been estimated upon cannot be used, but if this contingency occurs it is time for the factory superintendent or the general foreman to step in and find out why the castings or forgings are not what they should be.

CHAPTER XXII

ESTIMATING COSTS

Time Factor in Estimating Costs.—The problem of estimating costs of manufacturing work is one which is of interest to every manufacturer. In some cases a small factory is engaged in the building of jigs, fixtures, or other tools for outside concerns, and in many cases the firm which is doing the work is compelled to submit a bid in competition with other factories. It is therefore of the utmost importance to make sure that the bid which is submitted to the customer, is such that it stands a fair chance in the competition with the others. In order to make sure that the prices which are quoted to the customer are reasonable and proper, and at the same time that the estimate submitted is made with a wide enough margin to give a substantial profit to the manufacturer, a careful estimate of the time necessary to produce these various pieces which are to be made, is a very important factor.

Broad Experience Necessary.—This is one way in which the estimating of costs can be applied, but there are other applications which are fully as important. Let it be supposed that a manufacturing concern is about to submit a bid for making up a large number of pieces which are components of a

military rifle; or that a great number of shrapnel shells are to be made, and that the bids which are to be submitted are in competition with those of numerous other manufacturers who are looking for the same work. It is very evident, then, both that the manufacturer who intends to do this class of work should be well prepared as regards his mechanical equipment of machine tools and shop tools, and also that his engineering force be well fitted to make estimates of production and of the costs of machining. In the first place, either of the propositions mentioned requires the services of men who have had long experience in the shop, and also in the planning of operations for work which is to be done in quantity.

Let us take the case of the factory which is prepared to build jigs and fixtures. It is much more difficult for a concern of this kind to make an estimate on the cost of a jig or fixture, than to estimate the production which can be obtained for certain pieces of work which are being put through the factory in large quantities. In the case of the manufacturing of jigs or fixtures, the work must be re-set a number of times during the process of manufacture, and every precaution must be taken to insure accuracy. All these operations take a certain amount of time, the exact amount depending largely upon the skill of the tool-maker. It is therefore difficult to estimate this class of work as closely as the other kind mentioned.

In the case of the manufacturing of a great many parts of the same kind, it is entirely possible for

the manufacturer to provide means of holding and locating the work for the various operations which are to be done upon it in such a way that the parts will come to the desired size almost automatically. It is a matter of judgment. Unless the man who is selected for making estimates of this kind is one of broad experience, unless he has had a number of years of actual shop work, together with considerable experience in the actual engineering processes, and unless he has a logical mind, he is very likely to make a complete failure of estimating the cost of work which is to be done.

Usual Causes of Failure.—If a jig or a fixture is to be made up, and there is a drawing from which the estimate can be made, the estimator can proceed to take up the various machining operations which are necessary to complete the piece of work, and can jot down the amount of time which he thinks it would be necessary to consume for the various operations, always remembering to make due allowance for the time lost by the tool-maker in looking up tools and in setting up the work preparatory to the machining. Allowance must also be made for careful measuring, in order to insure proper accuracy in the finished product. It will be readily seen that in order to do this kind of work the estimator must be a man who has actually done the work in the factory, in order that he may know exactly how a man would be obliged to go to work to do the necessary machining. The usual causes of failure in estimating a piece of work such as that mentioned, are that sufficient allowances are not made for the setting

up and the getting ready to go to work, as well as for time which the man consumes in actually making the fixture.

Secret of Estimating Costs.—Briefly stated, the entire secret of estimating costs of production lies in allowing a man sufficient time to do the work, remembering at the same time that there are little incidental things which tend to increase the time necessary, because of a failure to find a certain tool that is wanted, or owing to difficulties that arise when castings or forgings are not made in exactly the right way. All these points must be taken into consideration by the estimator, and the time allowance must be made on an hourly basis. The amount of profit which is to be made by the manufacturer is dependent, to a great extent, upon the overhead expense in the factory. There are many other items, also, which must be considered in making up an estimate of the cost of production. Among them are the matter of the cost of material. In some cases the jig or fixture is made of cast iron, and the pattern is to be made by the same person who is to build the fixtures. In a case of this kind, it is obvious that the pattern-maker's time must also be charged against the account. Also, the amount of stock and the weight of the cast iron which goes to make up the jig, together with the cost of the iron in the jig, must be taken into consideration.

Skilled and Unskilled Labor.—Due time must be allowed for the hardening of any parts of the jigs or fixtures which are to be hardened, and it must also be remembered that after a part is hardened, it is

usually necessary to grind it, in order that the distortion caused by the hardening process may be removed and the piece may be properly fitted. Of course there are some parts which may be hardened without affecting the jig or fixture in its vital points in the process—for example, such things as the heads of screws or their points, a C-washer, a lever, or some other part of minor importance. No matter how small the piece of work may be, however, it must be considered in the making of the jig or fixture, and if there are a number of pieces of the same kind (such as locating pins or something of similar character), several of these pieces can be made up at the same time by a boy or an apprentice, or by a comparatively inexperienced man.

This being the case, the time for these various pieces need not be charged against the work at as high a rate as that charged for some of the actual tool-making. As a matter of fact, it is customary, in factories which do a considerable amount of this kind of work, to portion out such parts as can be made by an inexperienced man, and thus obtain the benefit derived from a cheaper rate of labor. In cases of this kind, the man who roughs out the part leaves a certain amount of work to be done or completed by the tool-maker, doing only the crudest part of the work himself.

No Hard and Fast Rule.—There can be no definite rule which a man can follow in estimating costs for work of this character. As stated before, it is always necessary to make a generous allowance for the setting up time and incidental time needed by the work-

men in obtaining tools from the tool room, and in making measurements, laying out the work, and so on. Let it be supposed that a number of jigs or fixtures of very similar character are to be made by a manufacturer for an outside concern. Then the estimator would consider that these various planing or shaping operations which are to be done on the work, can be carried along at the same time; if this plan be followed, a considerable saving in time will be effected.

There are so many conditions which affect the building of tools of this type, that it is a very difficult matter to go into the details of the processes used in different factories. About all that can be said in this regard has already been mentioned. A specific example or two could be given, but they would not serve any valuable purpose, and might only confuse the reader. However, in the estimating of costs for work which is to be put through the factory in large quantities, other factors which are more nearly stable come into play.

A Manufacturing Case.—Let us now consider the estimating of cost for a manufacturing proposition involving a number of pieces of a similar kind, which are to be made up entirely on an automatic screw machine. Under such circumstances it is a very simple matter to decide exactly which are the tools that must be used for the work, and since the material from which the work is to be made is of a certain character, and, furthermore, since the feeds and speeds of the machine can be easily determined, it is evident that a very close estimate of

the actual time needed to produce the work can be obtained without great difficulty. Let us assume further that the job includes a number of pieces which must be machined on an automatic screw machine, that a series of holes must be drilled in each piece, and that a single milling operation is called for. It will be seen that although this piece of work is somewhat more difficult to figure than the other one mentioned, it is nevertheless, a simple manufacturing proposition. In this latter case, however, it is necessary to take into consideration the fact that certain tools and fixtures must be made, if the work is to be done properly and is to come within the required limit. A jig and a milling fixture will both be necessary. The cost of these fixtures must be estimated, and the price must be included in the cost which is submitted to the customer for whom the work is to be done.

Overhead Expense. Hourly Basis.—The matter of overhead expense is so broad, and furthermore it is of such a variable character, that it is difficult to give anything more than a general idea of it in this chapter. Briefly, the overhead expense of a factory consists of a burden, or load, over and above the apparent cost of labor. That is to say, if a workman spends one hour in turning out a piece of work and if his rate is 30 cents an hour, this burden must be added to the workman's actual cost of labor, in order that the cost of equipment, cost of power, and various other costs, may be taken care of properly. In addition to these matters, the manufacturer's profit, and the depreciation of his machinery and equipment,

must also be considered, together with the percentage on the investment, in order that when the work is completed there may be a large enough profit to prove to the manufacturer that his business is a profitable one.*

It is evident that factories of different kinds and under different management would have a proportion of overhead expense that would differ according to the factory conditions and many other items pertaining to the management. In the past few years I have noted a wide difference between the bids submitted by different manufacturers on the same jigs and fixtures. This difference in prices makes it clear that either there is a tremendous difference in the way in which different manufacturers estimate on the same piece of work, or else the equipment which these various manufacturers use for producing the work is in some cases better adapted than in others to the class of work on which these prices were submitted.

Different Methods but One Principle.—One particular instance is worthy of mention. A set of blueprints of a group of three indicating gauges was sent to five different manufacturers, with a request for bids. The lowest bid received was $670, the highest bid was $1472. The work was given to the man whose bid was the lowest, and the work produced was of so high an order that it passed a most rigid inspection. It is evident from this case that the manufacturer whose bid was the highest would have been

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* A full discussion of the factors affecting the determination of burden or overhead will be found in Industrial Cost Finding, by N. T. Ficker, Factory Management Course.

able to make a very high profit on the work, had he succeeded in obtaining the contract, or that his operating methods were very inferior. As a matter of fact, I have found that many manufacturers who bid upon this class of work do not go to the trouble of figuring out all the details of manufacture carefully, but merely look over the work and form a rough estimate from their previous knowledge of how long it takes to do the work. To be sure, a man of wide experience can, even by this method, obtain a close approximation of the time necessary to produce a given piece of work, always provided that this man has had experience with other work of a similar kind. On the other hand, a careful estimator who has had the necesary shop experience and many years of actual shop training, can obtain a much closer approximation of the cost of production by figuring out the actual amount of work which must be done to complete the piece.

Evidently, then, different processes of estimating cost are used by different manufacturers. It is hard to say just what method is best suited to a particular class of work, since so many factors enter into the matter. It is always safe, however, to act upon the principle that the careful estimator who figures the work on the hourly basis will obtain, in the long run, a much more uniform and satisfactory estimate of cost than the man who depends upon snap judgment. Each manufacturer must be a law unto himself in this regard, but the careful man, who adopts the principle of "safety first," will find himself better off than the one who uses the "hit or miss" method.

CHAPTER XXIII

INTERNAL, EXTERNAL AND THREAD GAUGES

Accuracy Required in Interchangeable Manufacture.—When a number of parts are to be made that will be interchangeable one with another, it is necessary to make the parts within definite limits of accuracy. Before going into this subject let us first understand the different terms which apply to gauging and gauging systems. Let us also determine the use of a gauge and its applications to the work.

In the first place in assuming that a number of pieces of the same size are to be made, it will be necessary for the workman to measure each piece as he is producing it in order to be sure that the sizes are kept to the dimensions, unless a system of gauges is made for the work. He would use for this purpose a set of micrometer calipers and other measuring instruments of precision depending upon the class of work on which he was engaged. But as these instruments are all capable of being set to certain sizes, and are, therefore, flexible, it is obvious that in using these tools he must be able to discriminate in their application. He must guard against error in reading the micrometer, or other instruments. And, again, the continual use of such delicate instruments in manufacturing is not to be commended on account of the

wear involved. In order, then, to take the place of these delicate instruments, especial gauges can be made to give fixed readings; also in order to provide for slight variations in the work, "limit" gauges can be used.

Let it be supposed that automobiles are to be made up in large quantities complete in every part and on an interchangeable basis, such that one part if injured or worn out can be replaced by another which will be the counterpart of the previously used portion. Assuming that a condition of this kind is found, the first step in the gauging system must be a determination of the different kinds of fits which will be used in the different parts of the automobile. In this connection the quality of the product must be taken into consideration. That is to say, if an excellent machine is to be manufactured, the workmanship will be naturally of a high grade and, therefore, the allowances for the various fits must be consistent with the quality of the machine to be manufactured. Let us consider this matter in detail under the various headings given herewith.

Terminology.—When two parts are to be fitted together the relation of these parts to each other is in the nature of a fit of some kind. For example when a shaft is to be fitted to a bearing in such a way that it will revolve freely in the bearing, the fit will be called a "running fit". A "push fit" is somewhat closer than a running fit; the parts are not free to revolve, but can be assembled by hand without using much pressure. A "drive fit" is such that the parts can be assembled only by means of pressure under an arbor press or by driv

ing with a hammer. A "force fit" is such that the parts must be assembled by means of heat and hydraulic pressure.

It is evident that there may be several kinds of running fits; that is, there may be several grades of these fits. If we should assume that a farm machine, such as a harvester or mowing machine, was to be made, it would be apparent that such a machine subjected as it is to heavy usage and in the hands of men who are not mechanical, would need to be rather freely put together. This class of fit would obviously be less accurate than if the machine in question were to be an automobile or a sewing machine or some other type of mechanism requiring careful workmanship. Therefore it is plain that several grades of running fits must be made to suit different kinds of work. These matters are entirely dependent upon manufacturing conditions and also the requirements of the mechanism after it is completed.

Manufacturing conditions are such that it is easier to make shafts or studs to a size a little under or a little over a specified dimension than it is to make a hole over or under a given size. This is due to the fact that a hole is usually drilled, bored, reamed, or ground. It is not a very easy matter to make a reamer so that it will cut a hole much different from the standard size (although a new reamer is inclined to cut a trifle over-size, and after it is worn a little it may cut a little under-size). Therefore the size of the holes are usually kept as nearly to a standard as the uses of tools will permit. As a general thing it is not customary to put any kind of a limit on a hole which is to be drilled, but holes which are to be reamed or ground can be

machined within close limits of accuracy. It is well to state parenthetically at this point that as the hole is usually made as nearly standard as possible the limits of accuracy within which it must be machined are determined by conditions. The shafts or studs, however, which fit the holes are made within limits determined by the class of fit for which they are intended.

Terms Used in Gauging.—In mentioning the terms used to describe various points in connection with gauging, there are three words the meaning of which are not always clear to the average man. These terms are "allowance," "tolerance," and "limit."

The term allowance is used to describe the relation that one piece bears to another when the two parts are assembled. For example, if a shaft were to be fitted into a hole so as to revolve freely, it would be necessary to make an allowance between the size of the hole and the size of the shaft so that the right relation will be maintained between the two surfaces and permit the shaft to revolve with the proper amount of clearance and sufficient freedom in the hole. If a hole were to be reamed to 1 inch in diameter and a shaft were to be revolved in this hole, we can assume that an allowance of 0.001 inch must be made on the shaft under the size of the hole so as to permit free turning. It will be seen that the kind of fit which must be obtained between two pieces of work determines the possible allowance.

The term tolerance applies to the total amount of variation permissible in manufacturing any given piece of work. As an example, let us take a shaft 1 inch in diameter which must be machined to a given size.

Tolerance is determined by the machining possibilities and the quality of fit which is to be made. If it is supposed that the shaft is to be machined within a tolerance of 0.0005 inch, then the maximum and minimum variations must not differ by more than the amount mentioned.

The term limit is applied to the maximum and minimum size of work to be produced as determined by the tolerance. For example, if the work is to be made

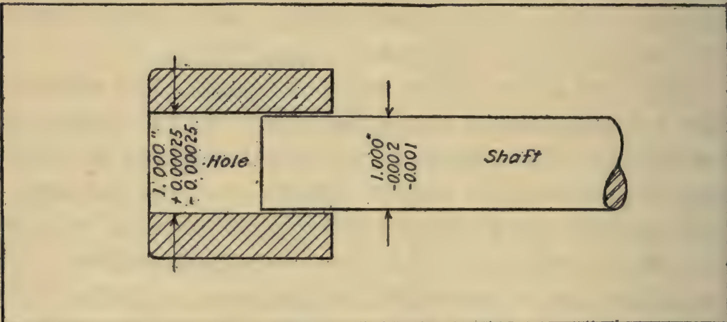

FIG. 139. DIAGRAM SHOWING APPLICATION OF LIMITS TO A SHAFT AND HOLE

within a tolerance of 0.0005, then the limits within which the piece may be permitted to vary must be such that their total amount will not exceed the prescribed tolerance.

Let us take a concrete example of the shaft and hole diagramatically shown in Figure 139. This illustration shows that the limits as set for the dimension of the hole are given in terms of plus (+) and minus (—). It will be seen that the shaft sizes are also given in limits but that the limits are both minus dimensions.

From the figures given on the diagram, the greatest amount of variation possible is as follows:

Maximum hole	= 1.00025
Minimum shaft	= 0.098
Clearance	= 0.00225
Minimum hole	= 0.99975
Maximum shaft	= 0.999
Clearance	= 0.00075

From the diagram and the foregoing figures it will be seen that in such extreme cases the allowance or clearance will be sufficient to obtain a running fit for the shaft in the hole. It is true that in the greater extreme the clearance is a little more than it should be, while in the smaller allowance the fit is a little closer than it should be; but if the gauges which are used for the work are properly used, there will be no doubt that the fits obtained are commercially good.

The principles shown in this diagram can be applied to other kinds of gauging, and it is an easy matter to determine whether the proper allowance, tolerance, and limit have been set for any given piece of work by means of a careful inspection of the results in maximum and minimum sizes obtained by following the limit given.

Setting Limits for Interchangeable Work.—Gauging work in order to produce interchangeable parts is dependent upon so many factors that it is out of the question to give hard and fast rules here that will be applicable to all conditions. Manufacturers have established no system of limits which fit every con-

TOLERANCES FOR STANDARD HOLES

(NEWALL ENGINEERING CO.)

Nominal Diameters, Inches..	0–1/2	9/16–1	1 1/16–2	2 1/16–3	3 1/16–4	4 1/16–5	5 1/16–6	6 1/16–7	7 1/16–8	8 1/16–9	9 1/16–10	10 1/16–11	11 1/16–12
CLASS A													
Max. Limit.....	+0.00025	+0.00050	+0.00075	+0.00100	+0.00100	+0.00100	+0.00150	+0.00150	+0.00175	+0.00175	+0.00175	+0.00200	+0.00200
Min. Limit.....	−0.00025	−0.00025	−0.00025	−0.00050	−0.00050	−0.00050	−0.00050	−0.00075	−0.00075	−0.00100	−0.00100	−0.00100	−0.00100
Tolerance......	0.00050	0.00075	0.00100	0.00160	0.00150	0.00150	0.00200	0.00225	0.00250	0.00275	0.00275	0.00300	0.00300
CLASS B													
Max. Limit.....	+0.00050	+0.00075	+0.00100	+0.00125	+0.00150	+0.00175	+0.00200	+0.00225	+0.00225	+0.00250	+0.00250	+0.00275	+0.00275
Min. Limit.....	−0.00050	−0.00050	−0.00050	−0.00075	−0.00075	−0.00075	−0.00100	−0.00100	−0.00125	−0.00125	−0.00125	−0.00125	−0.00150
Tolerance......	0.00100	0.00125	0.00150	0.00200	0.00225	0.00250	0.00300	0.00325	0.00350	0.00375	0.00375	0.00400	0.00425

TOLERANCES FOR RUNNING FITS

(NEWALL ENGINEERING CO.)

Nominal Diameters, Inches...	0–1/2	9/16–1	1 1/16–2	2 1/16–3	3 1/16–4	4 1/16–5	5 1/16–6	6 1/16–7	7 1/16–8	8 1/16–9	9 1/16–10	10 1/16–11	17 1/16–12
CLASS R													
Max. Limit.....	−0.00200	−0.00275	−0.00350	−0.00425	−0.00500	−0.00575	−0.00650	−0.00675	−0.00700	−0.00750	−0.00800	−0.00826	−0.00850
Min. Limit.....	−0.00100	−0.00125	−0.00175	−0.00200	−0.00250	−0.00300	−0.00350	−0.00350	−0.00350	−0.00375	−0.00400	−0.00400	−0.00425
Tolerance......	0.00100	0.00150	0.00175	0.00225	0.00250	0.00275	0.00300	0.00325	0.00350	0.00375	0.00400	0.00425	0.00425
CLASS S													
Max. Limit.....	−0.00125	−0.00200	−0.00250	−0.00300	−0.00350	−0.00400	−0.00450	−0.00475	−0.00500	−0.00550	−0.00575	−0.00600	−0.00625
Min. Limit.....	−0.00075	−0.00100	−0.00125	−0.00150	−0.00200	−0.00225	−0.00250	−0.00275	−0.00275	−0.00300	−0.00325	−0.00325	−0.00350
Tolerance......	0.00050	0.00100	0.00125	0.00150	0.00150	0.00175	0.00200	0.00200	0.00225	0.00250	0.00250	0.00275	0.00275
CLASS T													
Max. Limit.....	−0.00075	−0.00125	−0.00150	−0.00200	−0.00225	−0.00250	−0.00275	−0.00275	−0.00300	−0.00300	−0.00325	−0.00350	−0.00350
Min. Limit.....	−0.00050	−0.00075	−0.00075	−0.00100	−0.00100	−0.00125	−0.00125	−0.00125	−0.00150	−0.00150	−0.00150	−0.00175	−0.00175
Tolerance......	0.00025	0.00050	0.00075	0.00100	0.00125	0.00125	0.00150	0.00150	0.00150	0.00150	0.00175	0.00175	0.00175

TOLERANCES FOR PUSH, DRIVING AND FORCE FITS

(NEWALL ENGINEERING CO.)

Nominal Diameters, Inches...	0–1/2	9/16–1	1 1/16–2	2 1/16–3	3 1/16–4	4 1/16–5	5 1/16–6	6 1/16–7	7 1/16–8	8 1/16–9	9 1/16–10	10 1/16–11	11 1/16–12
PUSH FITS—CLASS P													
Max. Limit.....	−0.00075	−0.00075	−0.00075	−0.0010	−0.0010	−0.0010	−0.0010	−0.00125	−0.00150	−0.00150	−0.00200	−0.00200	−0.00200
Min. Limit.....	−0.00025	−0.00025	−0.00025	−0.0005	−0.0005	−0.0005	−0.0005	−0.00050	−0.00050	−0.00050	−0.00075	−0.00075	−0.00075
Tolerance......	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.00075	0.00100	0.00100	0.00125	0.00125	0.00125
DRIVING FITS—CLASS D													
Max. Limit.....	+0 00050	+0.00100	+0.00150	+0.00250	+0.00300	+0.00350	+0.00400	+0.00450	+0.00500	+0.00550	+0.00600	+0.00650	+0.00700
Min. Limit.....	+0.00025	+0.00075	+0.00100	+0.00150	+0.00200	+0.00250	+0.00300	+0.00300	+0.00350	+0.00400	+0.00450	+0.00450	+0.00500
Tolerance......	0.00025	0.00025	0.00050	0.00100	0.00100	0.00100	0.00100	0.00150	0.00150	0.00150	0.00150	0.00200	0.00200
FORCE FITS—CLASS [illegible]													
Max. Limit.....	+0.00100	+0.00200	+0.00400	+0.00600	+0.00200	+0.01000	+0.01200	+0.01400	+0.01600	+0.01800	+0.02000	+0.02200	+0.02400
Min. Limit.....	+0.00050	+0.00150	+0.00300	+0.00450	+0.00800	+0.00800	+0.01000	+0.01200	+0.01400	+0.01600	+0.01800	+0.02000	+0.02200
Tolerance......	0.00050	0.00050	0.00100	0.00150	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200

dition, and there is more or less diversity of opinion. Tables used by the Newall Engineering Co. are given on the preceding pages which may be helpful to a manufacturer in establishing a system of limits for his own factory. As previously stated, the class of work to be done has a great effect on the setting of limits for interchangeable manufacture, but a basis from which to work can readily be established and suitable changes made to suit requirements which later may be found necessary.

The man who establishes a system of manufacturing limits for interchangeable manufacture must always understand the requirements of the work to be done and its nature. He must know just where the finest working parts of the mechanism are situated and how closely these parts must be fitted in order to give the results required. The conditions of manufacture must always be considered, and the vital parts of the mechanism must have special attention. As previously mentioned, tolerances for all work should be as great as possible consistent with the quality of the work to be produced.

In this connection it is well to mention the unfortunate practice of the majority of manufacturers in regard to shaft lengths. It is seldom that they prescribe limits on this class of work, and therefore the workman in making a shaft is unable to determine how closely the shoulders must be made to the given sizes on the drawing. In order to obviate any trouble in this regard it is good practice to establish a system of some sort to govern such work. It must always be remembered that small tolerances mean careful work

and that careful work is always expensive. Therefore it is highly advisable to specify the limits on shafts and shoulders in order to obviate difficulties in machining. It is frequently possible to give shoulder tolerances on shafts of 1/64 or 1/32 of an inch, and when it is possible to give such tolerances the cost of machining will be much more reasonable.

Many manufacturers set tolerances entirely too close in the effort to obtain a fine product. Some even go to the expense of finishing parts which do not fit others in order to improve the appearance of the finished product. Such practice as this is expensive and unnecessary, except in cases where parts must be balanced on account of the high rate of speed at which they are to run or else to prevent vibration due to excessive speed and lack of perfect balance. All these points must be considered in the setting of limits, and therefore it is very obvious that the engineer who does this work must be perfectly familiar with the product in its actual working points.

Marking Limits on Drawings.—The marking of drawings with limits is commendable, and much confusion can be avoided by using fractional dimensions for all unimportant sizes. A notation can be made on the drawing to the effect that an error of 1/64 + or — is permitted on fractional dimensions given on the drawing. Decimal dimensions can also be used to indicate tolerances to a certain degree, although this practice in general is not recommended. There may be a notation or an understanding in regard to the matter, however, such that if decimal dimensions are given to four places of decimals, the work must

be kept within a limit of plus or minus 0.0005; if three places of decimals are given on a drawing then the limit is to be kept within 0.001 plus or minus; if two places of decimals are given on the drawing then it may be understood that a limit of 0.005 plus or minus is permissible. The better way, however, is to mark the drawings positively with the limit whenever possible, so that there is no chance for errors on the part of the workman.

Internal Limit Gauges.—If it is necessary to machine a hole within certain limits of accuracy, a gauge should be provided which is so constructed as to permit the workman to use it in determining whether he has produced the work within the required size or not. If the hole to be measured is a cylindrical one of small size, say 2 or 2½ inches, then the type of gauge which is used is termed a plug gauge. And if the hole to be gauged is tapered, the type of gauge used is termed a taper plug gauge. If the hole is threaded, the gauge used is called a male thread gauge. These three gauges are of different types and are made differently to suit the various kinds of work for which they are to be used.

A limit gauge is a gauge so constructed as to determine more or less automatically whether work has been made within the specified limits or not. There are several types of gauges for this purpose, which differ from each other only in certain details of construction; the principles on which they are based are the same. The type used for gauging a cylindrical hole has one end made of such size that it will just enter the hole providing the hole has been made large

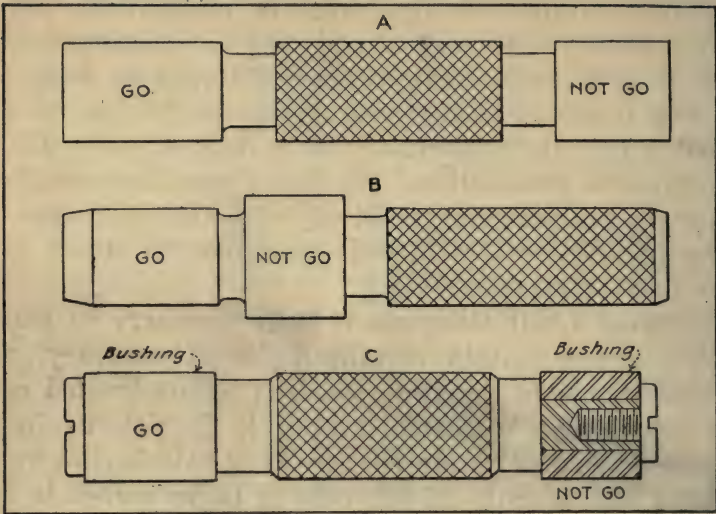

FIG. 140. SEVERAL VARIETIES OF PLUG GAUGES

enough; the other end is very slightly larger than the hole should be, the difference in size being the extreme limits or tolerance permitted in the work. Therefore a gauge of this kind is frequently spoken of as a "go and not go" gauge, meaning that one end should go into the work and the other end should not go. Sometimes the go and not go portions are on the same end of the gauge.

Referring to Figure 140, the two types of gauges commonly used will be noted at A and B. The upper figure, A, shows the double-end plug gauge, and the lower figure, B, has both of the limiting portions on one end. The lower type, B, is to be preferred for work in which the hole extends completely through the piece, as the workman in this

case is not obliged to turn the gauge end for end in using it. These gauges are often made with a slight taper on the end, in order to facilitate their use.

Another type of plug gauge for cylindrical work is shown at C in the same figure. This gauge does not differ from the one indicated at A in any respect except that the go and not go portions are made in the form of bushings which can be removed and replaced with others in the event of their becoming worn. Although gauges of this kind cost a little more to produce, they have many advantages, which are plainly apparent, in the line of upkeep.

Internal Taper Gauges.—The gauging of a tapered hole is an entirely different proposition from the gauging of a cylindrical one, for two gaugings are required, namely, the taper itself and the diameter at the large end of the hole. It is obvious that a tapered hole is made to fit a tapered shaft or something of similar nature. In a gear which is made with a taper hole, for instance, the gear must be made to mesh correctly with its mate, and therefore its longitudinal position on the tapered shaft is important. This means that the tapered portion must be of such a diameter at the large end that it will slip upon the tapered shaft to a definite distance and fit snugly on the shaft at the same time that it attains its correct position longitudinally. It is plain, then, that a gauge for such a piece of tapered work must be so made that it will determine the taper as well as the distance that the actual fit will take place on the shaft.

As it is rather difficult to measure a tapered hole

at the large end, or in fact in any other portion of the hole, without special instruments. The method used in gauging the diameter is by the distance that a marked section of the gauge enters the large end of the work. By reference to Figure 141, the type of gauge used for a tapered hole will be clearly noted. This gauge is a limit taper gauge, and the

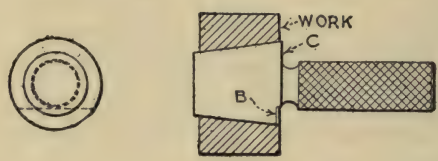

FIG. 141. TAPER LIMIT GAUGE FOR INTERNAL TAPERED HOLE

limiting portions are determined by the flatted part, B, on one side of the gauge and the cylindrical portion, C, which extends beyond it. Now when this gauge is used in a tapered hole, the operator places it in position and notes whether the flatted portion is below the surface of the hole or not. If he finds that it is below the surface and that the opposite side of the gauge, C, remains slightly outside of the work, then he is certain that the work has been made within the required limit longitudinally.

In addition to the longitudinal dimension, however, it is necessary to determine whether the taper

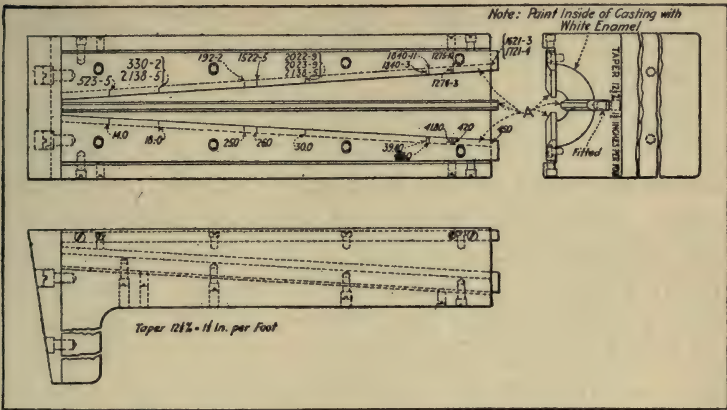

FIG. 142. FEMALE MASTER GAUGE FOR TESTING MALE TAPER GAUGES

is correct or not. As a general thing the taper in a hole is determined by means of a special tapered reamer and, therefore, there is little chance for variation at this point. However, in order to determine the taper with certainty, the inspector may use a little Prussian blue on the gauge and by revolving it slightly in the hole, he may see whether it is in contact along its entire length or not.

In connection with the use of taper gauges and, in fact, other types of gauges, mention should be made of the necessity for reference gauges. Gauges of this kind are made with great care and should be kept in a safe place so that they will not be subject to injury or marked variations in temperature. It is apparent that a reference gauge for a male taper gauge, such as that just described, would be such that when placed in conjunction with the reference gauge any variation might be readily detected. A

male gauge is usually tested by placing it in a female gauge, and conversely a female gauge is tested on a male gauge.

When a number of tapers of different diameters but of the same angle are to be tested, a reference gauge like that shown in Figure 142 can be readily made. This gauge is marked with the piece numbers and the limits in such such a way that the accuracy of the gauge to be tested can be quickly determined. This gauge is made with three adjustable blades of steel to facilitate manufacture. After the gauge has been set properly by means of suitable measuring instruments, the screw holes can be filled with wax or composition so that they cannot be tampered with.

Male Thread Gauges.—When an internal thread is to be gauged the type of gauge used is generally called a male thread gauge. The gauging of a thread requires special precautions as there are so many points to be determined: First, there is the diameter of the thread at the pitch line; second, the angle of the thread; third, the diameter of the hole at the bottom of the thread; fourth, the lead of the thread.* The ordinary commercial gauge only gives an approximation of these four points, otherwise several gauges would be needed to determine whether a thread was correctly made or not.

The simplest form of thread gauge is a piece of

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* The *lead* of a thread is the distance from the center of one thread to the center of the next, measured longitudinally. That is, in a 16 pitch thread, the lead is $\frac{1}{16}$ inch, because there are 16 threads to the inch. On multiple threads, *i. e.*, double or quadruple threads, *lead* denotes the longitudinal distance from one thread to the same thread after it has passed once around the piece. Thus the lead of a 16 pitch thread quadruple, would be $4 \times \frac{1}{16} = \frac{1}{4}$ inch.

steel threaded on both ends, one end of which is made so as to enter the threaded hole and the other end slightly larger so that it will not enter the threaded hole. This type of gauge is clearly shown in Figure 143. Commercially, a gauge of this type gives results sufficiently close to the limit.

The majority of threaded holes are made by taps, and if the thread gauge does not enter the work freely, it is generally found that something is the

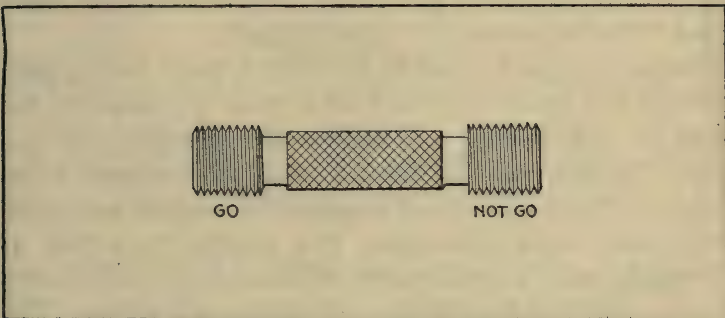

FIG. 143. STANDARD TYPE OF MALE THREAD GAUGE

matter with the tap that has been used. The taps should then be examined to find where the error lies and be discarded if found faulty. In most cases it will be found that a variation in the lead is the cause of the trouble. The tap may have been made up properly and have changed considerably during the hardening process, so as to give a lead slightly different from what it should be. It is an easy matter for a workman to tap a hole to the proper size, but if the lead of his tap is incorrect, great difficulty may be found in assembling the parts after they have been machined. A variation in the lead of the thread

means that only a few threads will be doing all the work while the other ones are free.

Several instruments are made for measuring the lead of a screw, based on the pitch line measurement. Usually these instruments are provided with ball points to reach down into the thread and measure directly on the pitch line. The type of thread gauge shown in the illustration is practically the only one which is commercially used today. The amount of tolerance permitted should never be more than 70 to 80 per cent of a full thread.

Some gauges are made in such a way that a portion of the gauge will act as a plug to measure the root of the thread or, really, the diameter of the hole. In this case the thread itself is measured separately. The majority of commercial screws are made with two much clearance; this results in a loss of strength and is productive of considerable difficulty when used on machinery otherwise all right. The result of poor workmanship on threaded work is that the threads, not having a full bearing, strip easily and are generally useless. The limit on threaded work should be sufficient to avoid such conditions.

External Gauges.—External gauges are made for cylindrical, taper, or threaded work. There are several kinds: snap gauges, ring gauges, receiver gauges, and female thread gauges. The snap gauge is the most common and is used for gauging cylindrical work. The ring gauge is generally used for reference, although occasionally it is used for actual gauging processes. Receiver gauges are made for determining several diameters at the same time and also for taper

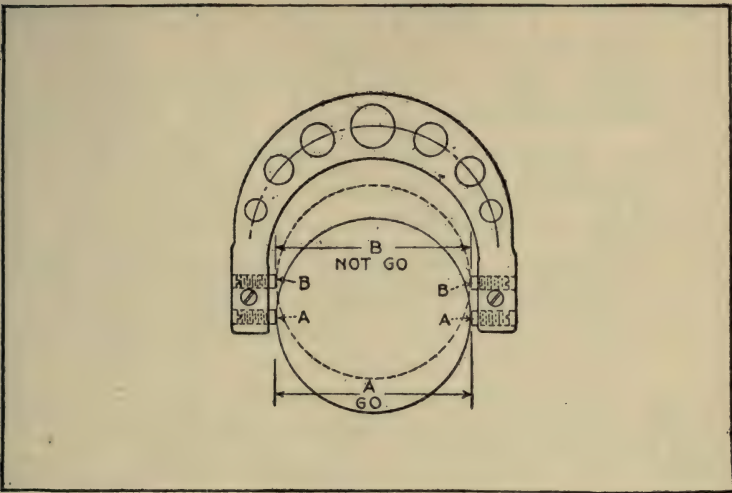

FIG. 144. STANDARD TYPE OF SNAP GAUGE WITH ADJUSTABLE POINTS

work. The female thread gauge is used for gauging male threaded work, such as screws and the like.

In gauging cylindrical work which is to be held within definite limits of accuracy, the snap gauge shown in Figure 144 is commonly used. This gauge is provided with surfaces or pins which limit the amount of variation, as shown at A and B in the illustration. The "go" portion of the gauge is represented at A; the "not go" at B. This gauge is used directly on the work and is extremely simple. As an example, let us suppose that a piece of cylindrical work is to be held within the dimension 0.998 and 0.996. Then A would be made 0.998 and B, 0.996; hence if the work were to be made so that it will enter A and not go between the points B, it is

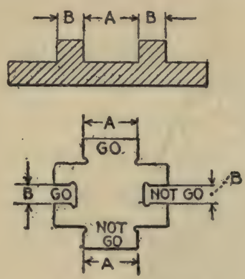

FIG. 145. SNAP GAUGE FOR MORE THAN ONE DIMENSION

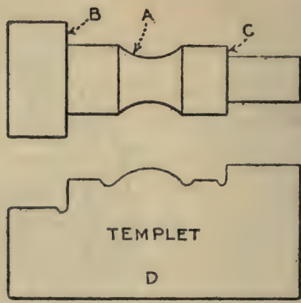

FIG. 146. TEMPLET GAUGE FOR A SPECIAL STUD

sure to be right. When this gauge becomes worn, the points A and B can be adjusted by size blocks or reground to size. In order to avoid either accidental or intentional changes, it is well to pour melted wax into the holes at the adjustable points, or else to put a drop or two of solder at these points so that no change can possibly be made without permission from the inspection department.

Snap Gauges for Widths.—Gauges of the snap variety are also used for determining widths across lugs and between them, for shoulder distances on shafts, for distances between bearings, and for other work of like character. Sheet metal gauges are frequently made for this purpose, and several gauging points can be made on a single gauge. For example, having a casting, such as shown above in Figure 145 in which the dimensions A and B are to be gauged, a snap gauge similar to that shown in the lower por-

tion of the figure can be employed. This type of gauge is made up of sheet steel, usually 1/8 to 3/16 inch in thickness, and hardened after it has been made very close to size. After the hardening, the gauging points or surfaces are carefully ground to correct dimensions. Gauges of this kind can be used in confined situations, and as they can be cheaply made their use is almost infinite.

Templet Gauges.—Frequently it is necessary to determine the form of a piece of work after it has been machined, especially when the shape of the piece is more or less irregular. Take as an example the work shown in Figure 146, in which the general form and correct spacing of A, B, and C are essential. In a case of this kind a templet gauge, similar to that shown at D, can be made to the form desired and the workman can use it when making up the piece, applying it to the work from time to time to obtain correct spacing and form.

The templet gauge as ordinarily used is not, however, an accurate method of gauging for it does not "tell the story," but only determines whether the shape of the work is correct or not. It does not show just where the points of inaccuracy are, but it does show that the piece is not correct if it does not fit the gauge. When it is necessary to gauge the contour of a piece of work within close limits of accuracy, another type of measuring instrument, termed an indicating gauge, can be used. This type will be described in the next chapter.

Perhaps one of the most useful applications of the templet gauge is in the manufacture of bolts, cap

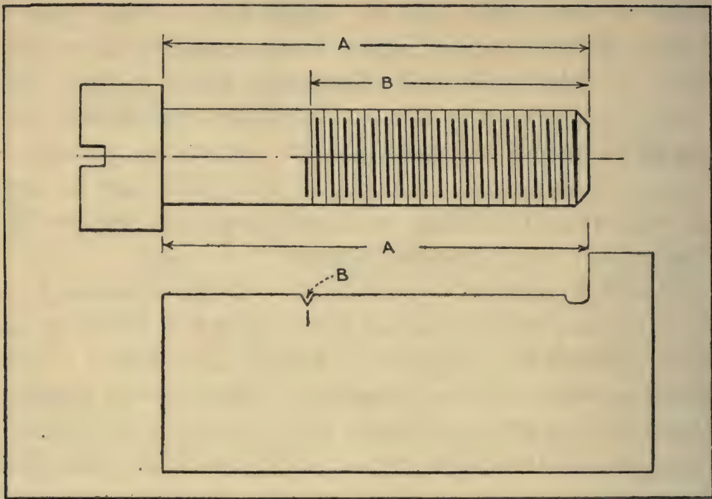

FIG. 147. TEMPLET GAUGE FOR A SCREW

screws, studs, and the like, for determining the length of the work and the length of the thread. As an example, let us take the screw shown in Figure 147 in which the length, A, is 3 inches and the length, B, of the thread, 2 inches. A gauge can be made for this work similar to that shown in the lower part of this illustration. Its application is obvious: both the length of the work and the thread can be noted in an instant when the gauge is applied. There are many other uses to which the templet gauge can be adapted, and the forms used are naturally dependent upon the work to which they are to be applied.

Ring Gauges for Cylindrical Work.—Ring gauges, such as that shown in Figure 148 at K, are used in a large degree for reference, but they are also occasionally called for in connection with manufacturing

on certain classes of work. The ordinary snap gauge as used on cylindrical work simply gives the diameter of the work at certain places where it is applied, but it does not show the variations along the shaft, nor does it determine whether the work is uniform in size at all points.

Let us take the piece of work shown in Figure 148 as an example: Here we see a shaft on which another member is to have a sliding fit from A to B. In gauging this shaft, the snap gauge would be used at two or three points, as at C, D, and E, and it will be assumed that the remainder of the shaft is correct, providing these points pass the inspection. By referring to the exaggerated view, much enlarged, of the same shaft, it can be seen that if the work is found to be imperfect, as shown at F, G, and H, the

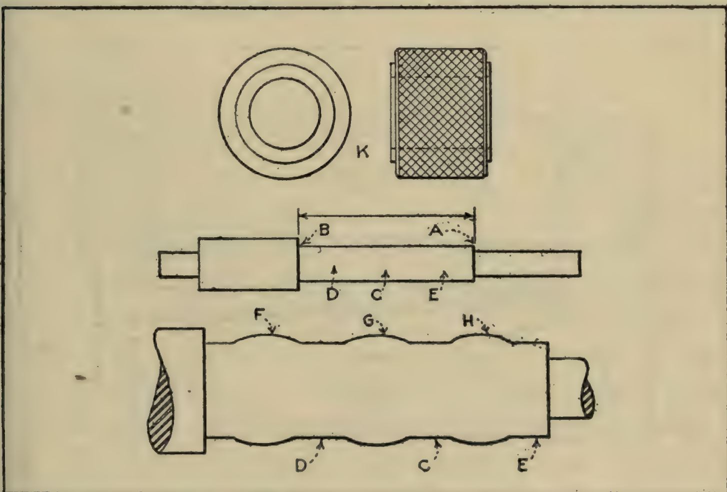

FIG. 148. CYLINDRICAL RING GAUGE, SHOWING APPLICATION

snap gauge will not reveal the defect. But if the ring gauge, K, were to be passed over the work from A to B, the trouble would be located immediately. For work of this kind, therefore, the snap gauge can be used as a work gauge and the ring gauge for the final inspection. The workman can then gauge the work for diameter, and the inspector's test with the ring gauge will show any variations along the length.

Receiver Gauges.—On certain classes of work, such as the components of rifles, sewing machines, typewriters, and adding machines, it may be found necessary to gauge every part of the piece as a final check against errors in machining. In this work a receiver gauge can be employed to advantage. This instrument is so made that the work can be placed in the gauge itself, and if the piece of work has been correctly made within the required limits of accuracy, it will conform

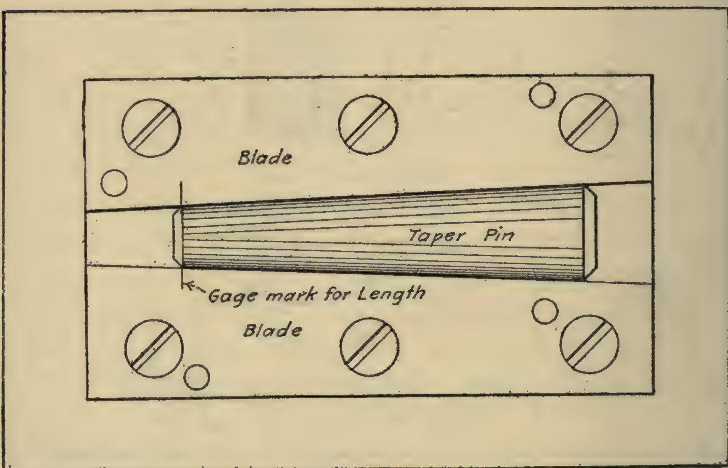

FIG. 149. RECEIVER GAUGE FOR TAPER PINS

closely to the contour of the receiver. Gauges of this kind can be made as limit gauges if desired, either by making them up with a series of sliding points to indicate the limits of variations permissible, or by making two gauges in one of which the work must go and in the other not go. Sometimes it is necessary to gauge a contour very carefully, and in cases of this kind an indicating gauge can be employed, as described in the next chapter.

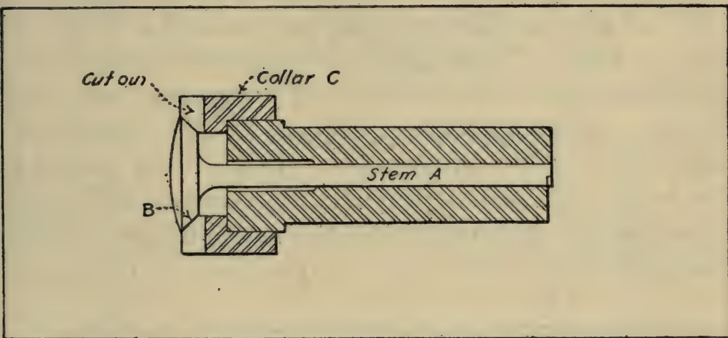

FIG. 150. RECEIVER GAUGE FOR A POPPET VALVE

A common form of receiver gauge is that shown in Figure 149, which is made for taper pins. Reference to the illustration will show that it consists of a base plate and two blades, one of which may or may not be adjustable. In using this type of gauge the pin is simply laid between the two blades in order to note whether the taper corresponds to that of the gauge or not. An additional refinement can be incorporated in this gauge by placing a mark on one of the blades to gauge the diameter of the taper pin by determining its length.

Another application of the receiver gauge is shown in Figure 150. This gauge is made for a poppet valve, in order to test the concentricity of the stem, A, and the valve seat, B. In addition to these points the angle of the seat can also be gauged. It will be noted that a part of the collar, C, is cut away to permit inspection along the seat of the valve. Many applications of this type of gauge can be made when the nature of the work warrants it.

Taper Ring Gauges.—In gauging a taper shaft or work of similar character several varieties of gauges may be used. These gauges are usually made from a cylindrical piece of steel having a tapered hole, such as that shown in Figure 151 at A. The limits are taken care of by cutting away half of the gauge at the large end, as noted at B. The correct size is determined by the junction of the tapered portion with the cylindrical part and the position of the gauge

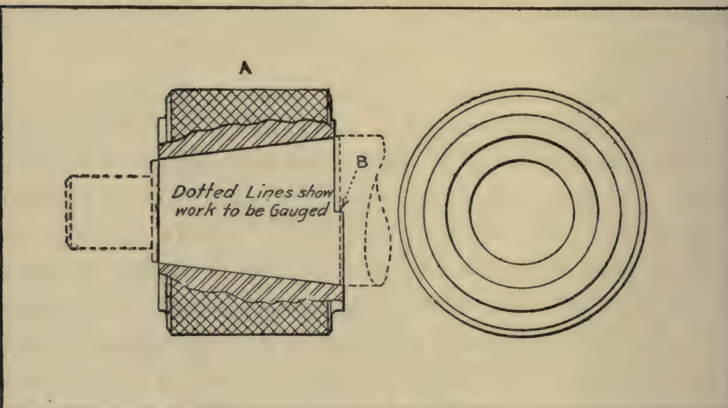

FIG. 151. FEMALE TAPER LIMIT GAUGE

longitudinally on the work. The gauge should not push onto the work far enough so that the flat part comes beyond the junction of the tapered and the cylindrical part. The taper itself is found to be correct or not by placing the gauge in position on the work which has been coated with a thin film of Prussian blue and giving it a slight turn to determine whether the taper is touching at all points.

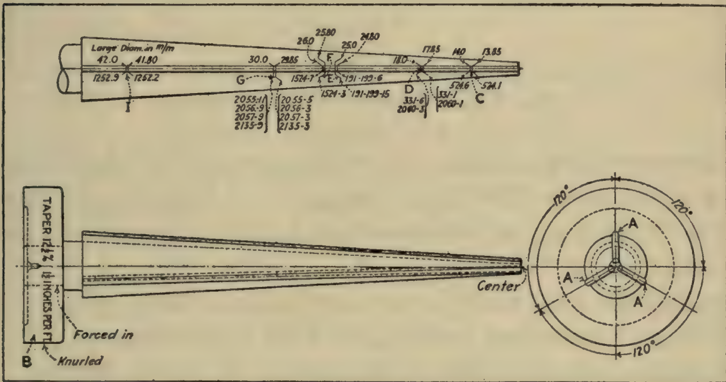

FIG. 152. MALE MASTER GAUGE FOR TESTING FEMALE TAPER GAUGES

Master Taper Gauge for Female Gauges.—As a reference gauge to which a female gauge may be applied in order to determine whether it is correct or not, a form such as that shown in Figure 152 can be advantageously used when all of the tapers to be gauged have the same angle. This gauge was designed to go with the female gauge shown in Figure 142. But in this case the gauge is intended for testing female taper gauges while the other is intended for testing male taper gauges. It will be seen that

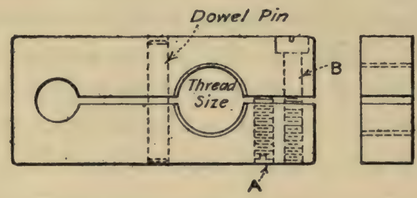

FIG. 153. FEMALE THREAD GAUGE

there are three blades, A, which are set into a column of steel supported by a base, B. Along the blades, the limits for various sizes of tapers are marked, as indicated at C, D, E, F, etc. In use, then, a master gauge of this kind is set up on its base, the ring gauge is dropped over it, and an inspection will determine whether the ring gauge is made correctly both as to limit and proper taper. Gauges of this kind which are intended for reference only should be preserved very carefully and never used for anything except reference.

Female Thread Gauges.—When a piece of threaded work, such as a shaft or stud, is to be gauged on its threaded portion, the testing is usually done by screwing the work into a female thread gauge, such as that shown in Figure 153. This gauge is made from a piece of steel of rectangular form and is drawn together or separated, as the case may require, by means of the set screws indicated at A and B.

Adjustment is simply for the purpose of finishing the gauge to the correct size with as little difficulty as possible. It also provides a slight adjustment after the gauge has become worn.

Gauges of this kind are seldom made with limits; but for very particular work two gauges can be used, one of the "go" variety and the other of the "not go." For ordinary commercial work which does not require very close limits of accuracy a gauge of this kind will be found sufficient.

For determining whether the lead of the thread is correct, a separate instrument must be used, as described in the next chapter. In general, threads of this kind are not gauged for the lead unless they are particularly important, in which case the indicating type of gauge is used to determine the correct lead.

There are other types of external and internal gauges which are used for special purposes, but the majority of them are modifications of those which have been shown or else they are of the indicating type of gauge for determining variations in inside or outside contours. The description of such of these gauges as are not mentioned in this chapter will be taken up in the following chapter.

CHAPTER XXIV

PROFILE AND INDICATING GAUGES

Gauges for High Accuracy.—The present tendency in gauging methods is to do away as far as possible with all gauges which do not show the amount of variation in the work. Many of the gauges described in the previous chapter are made to indicate whether a piece of work has been finished within the required limits or not. The workman, in using ordinary limit gauges, has no means of knowing (except the sense of feeling) how nearly he is approaching the limits which are permissible. His first real knowledge that his tools have "gone the limit" is when his gauge tells him so. Hence it will be seen that for work requiring a high degree of accuracy, the ordinary types of limit gauges do not quite answer the purpose. For such conditions, then, some other type of instrument by means of which the actual variations in the work can be accurately determined, is essential.

Now let us see what principles can be used in gauging work, keeping it within the prescribed limits and at the same time indicating the variations which are taking place from time to time because of the wear and changes in size of cutting tools. It is evident that indicating instruments which will show

variations in the work make it possible for the workman to change his tools as may become necessary and thus keep the work much closer to size than if the ordinary limit gauges were used.

For instruments of this kind variations in the work can be shown by a pointer of some sort working over a graduated scale; by the sense of touch in the workman's fingers as they are passed over one or more movable points; or by the sense of hearing, as in the case of a gauge showing limits by an electric contact which rings a bell or operates a buzzer. Of these three types, the dial-indicating, or multiplying-lever type, is most common. This gauge has a sensitive movable pointer which works on a graduated scale or dial, and can be adapted to an infinite number of uses in gauging. The "feeler" or "flush pin" gauge is also used to a considerable extent on work of irregular form, or for depth gauging; it is sometimes found convenient to use it also in the case of determining a correct shoulder distance. Micrometer gauges are also used to some extent on work requiring the highest degree of accuracy. And finally, there is a type of gauge which employs a delicate and sensitive arm so arranged that it multiplies the actual variation in a piece of work; if the variation is too great, it rings a bell by an electrical contact, or shows a red or green light if this scheme is preferred.

Standard Instruments of Precision.—Any mention of gauging systems which does not include some of the standard measuring instruments would be incomplete, but as we are for the most part concerned

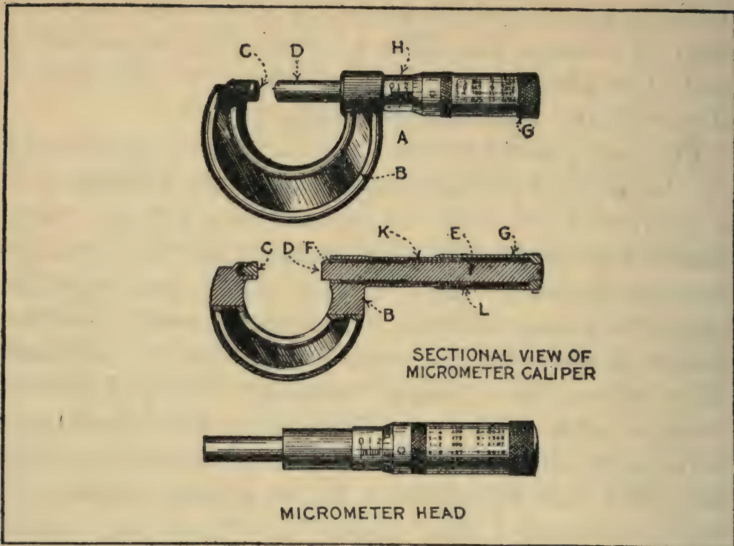

FIG. 154. MICROMETER GAUGES SHOWING CONSTRUCTION FEATURES

with special gauges, we will not devote a great amount of space to instruments which are adapted to the most minute variations, such as micrometer and vernier calipers and other instruments of precision. But as the principles on which these instruments are based are also applied to gauging certain kinds of work, let us look into the fundamental points on which they depend for their accuracy.

The micrometer caliper, shown in Figure 154, is familiar to all, and a brief description is all that will be necessary. The upper portion shows at A a general view of the instrument; a sectional drawing just below, gives an excellent idea of the construction. The frame, B, is a drop forging which is supplied

with a hardened inserted anvil, C. The frame is bored out and has an adjusting nut, K, inside and a short nut, L, to compensate for the wear on the threads. The screw, D, is threaded at E, and is fastened to the thimble, G, so that it can be rotated by the fingers of the operator. Each revolution of the screw moves it longitudinally 0.025 inches. The upper view shows the graduation on the thimble; and as there are 25 of these, starting with 0 and running to 25, each division represents 0.001 inch. It will be seen that by placing the work between the points C and D and adjusting the screw by means of the thimble, an accurate reading can be easily obtained. This type of instrument is used all over the world for accurate measuring. The micrometer head shown in the lower portion of the same figure is sold as a separate instrument and can be applied to many forms of gauging by mounting it on a suitable fixture to conform to the work which is being gauged.

Dial Indicator.—Another form of gauge, useful for inspecting a number of parts of the same kind, is shown in Figure 155. This instrument may be adapted to a variety of work by mounting it on a suitable holder to fit the conditions. It should not be considered as a gauge, however, but more as an indicator to show variations in size after setting it to a size block or plug. This instrument consists of the base, A, on which is erected a vertical shaft, B, absolutely perpendicular to the base. A sliding lever acts on this shaft as a holder for the dial indicator, C. The sleeve can be vertically adjusted and clamped at any desired height by means of a thumb screw

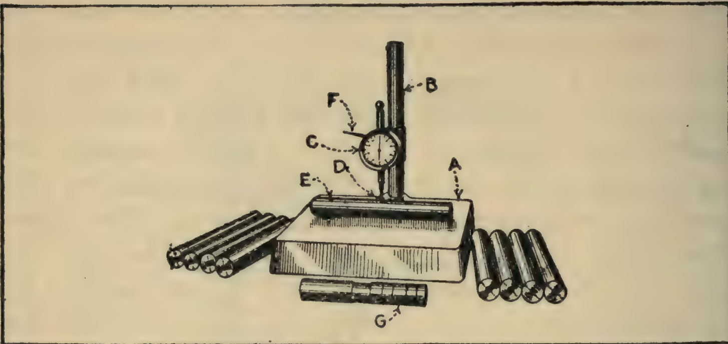

FIG. 155. AMES DIAL TEST GAUGE ARRANGED FOR INSPECTION OF SHAFTS

(not shown) at the rear of the instrument. The gauge point, D, is connected with the dial by means of a multiplying device inside of the instrument case, and the dial is graduated to read in thousandths of an inch, or finer if desired. In operation, a plug of the desired size, similar to that shown at G, is used for setting the gauge and indicator so that the pointer will read 0 if the work is correct. A piece of work, such as shown at E, is then passed under the gauge point, D, and the reading is noted. Variations can be quickly determined in this way, and a number of pieces tested one after the other. Indicators of this type are also frequently mounted on special gauging fixtures for special work.

Prestwich Fluid Gauge.—There has been a demand for many years for an accurate indicating gauge reading to one ten-thousandth part of an inch or finer, and a number of instruments are now on the market which will give readings as close as this, but

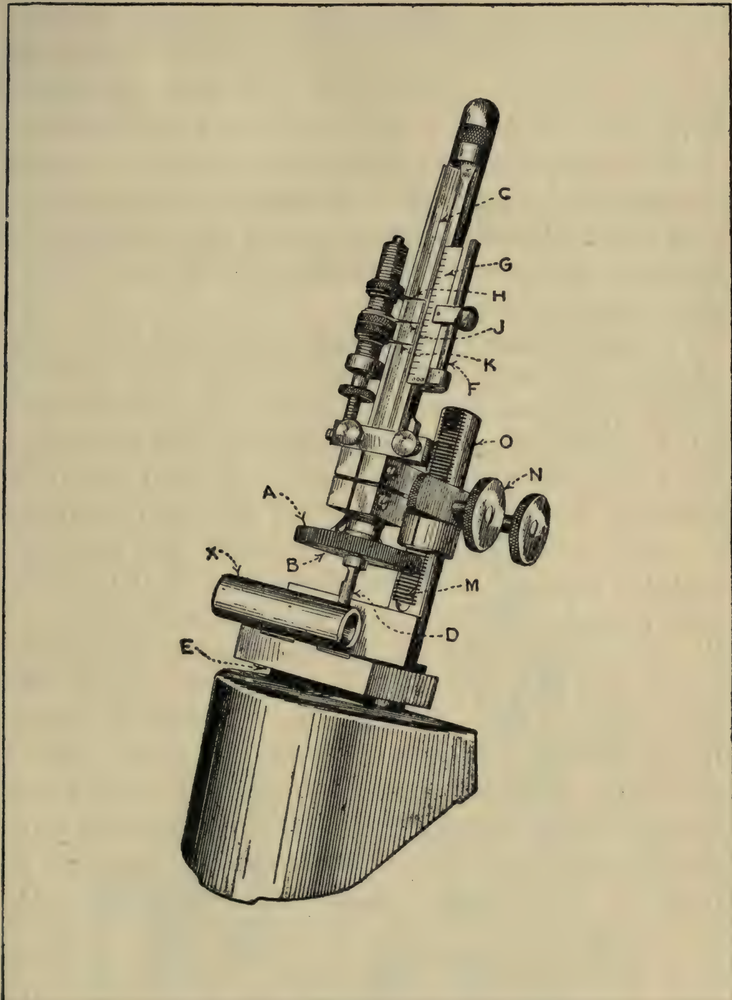

FIG. 156. PRESTWICH FLUID GAUGE

they are quite delicate in construction and require careful handling as well as care in reading.

The recently developed gauge shown in Figure 156, however, answers the demands of modern engineering work most admirably, and the reading of the instrument is so plain that a variation of one ten-thousandths part of an inch is discernible across an ordinary room. Furthermore the work can be gauged to specified limits, with the gauge set to meet the requirements of the work.

For ball bearings, thread gauges, or any other work which needs to be calibrated in large quantities and within very close limits of accuracy, an instrument of this kind is indispensable. The principles involved in the construction are as follows: A fluid-containing chamber, A, is provided with a flexible diaphragm, B, and a glass tube, C, finely bored and connected with the chamber, A. The diaphragm, B, is furnished with a hardened steel pin or anvil, D, and the base of the instrument also has a fixed anvil, E, between which and the anvil, D, the work is passed when calibrating. The chamber, A, contains a colored liquid which rises and falls in the glass tube, C, according to the pressure applied to the anvil, D, and transmitted to the diaphragm. The large area of the diaphragm in comparison with the fine hole for the liquid in the tube makes possible such a fluctuation in the tube that it is easier to determine variations of a ten-thousandth of an inch with this instrument than it is to discern a thousandth with most other measuring instruments. The chamber, A, is provided with a thread and micrometer index and a pointer on

the upper surface, as indicated, to show thousandths of an inch. This portion of the instrument is made for the purpose of obtaining rough adjustments; but it is not used after the instrument has once been set to the size desired. The carrier, F, is furnished with a scale, G, and three adjustable pointers, H, J, and K. The upper two of these pointers are so arranged that they can be set to indicate the tolerance limit between which it is desired to keep the work when gauging. The lower pointer, K, is set to the normal level of the fluid in the glass tube, C, so as to compensate for any fluctuations from changes in temperature. The instrument is roughly set to the size desired by means

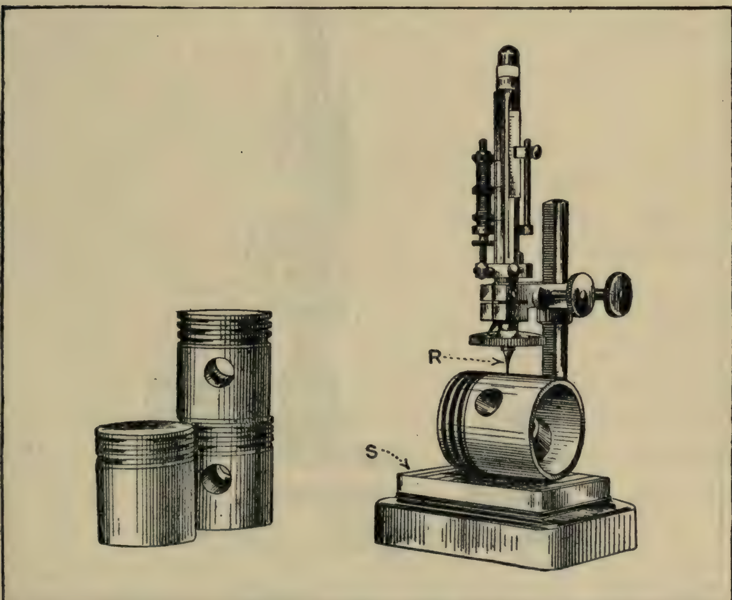

FIG. 156-A. PRESTWICH GAUGE USED IN GAUGING A PISTON

of the rack, M, and the pinion, N, on the pillar, O, to suit the piece which is to be gauged. The clamping screw is then tightened, and the final adjustment is made by the micrometer dial, A, to a standard gauge or a piece of the given dimension.

In the illustration, a piston wrist pin, X, is being gauged, a small special angle plate being set on top of the anvil, E, for this purpose, as clearly indicated. It is evident that a reading can be taken on a pin of this kind by simply pushing it along and noting any fluctuation in the column of liquid, C.

Referring to Figure 156-A, the same type of gauge

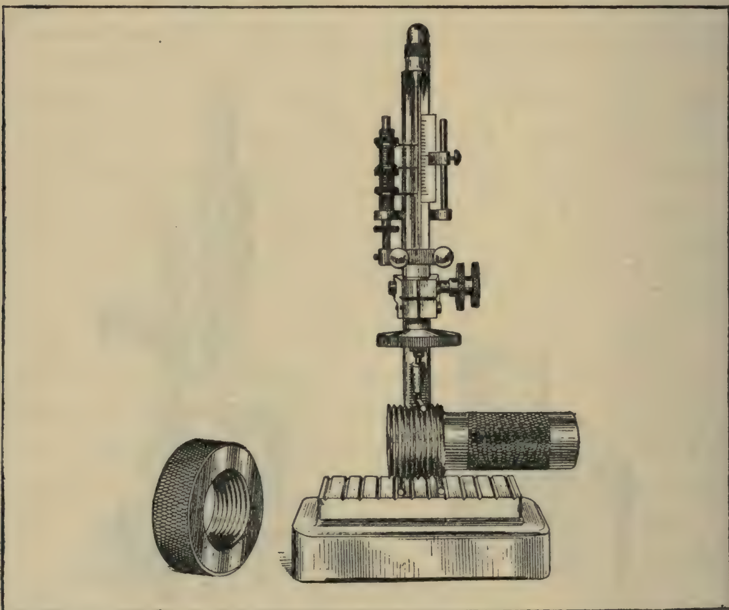

FIG. 156-B. PRESTWICH GAUGE USED FOR INSPECTION OF THREAD GAUGES

is shown applied to the measurement of an automobile piston. In this case it will be noted that the base of the gauge is furnished with a special block, S, and that a different indicating point, R, is used.

In testing a thread gauge, such as that shown in Figure 156-B, another application of this most useful gauge is found. In this case the indication point is of special form, permitting the "three-wire system" from the fixed diameter to be used. It will be seen that with this improvement, thread gauges or work of similar character can be determined with the utmost nicety and that the most approved system of gauging from the pitch diameter can be adopted. This gauge can be applied to many other varieties of special work, and its sensitiveness and facilities for quick and accurate reading make it invaluable to the progressive manufacturer.

Flush-Pin Gauges.—The flush-pin gauge is without doubt the simplest type of gauge based on the indicating principle. Several applications can be made of this principle, one of the most useful of these being the measuring of depths or shoulders.

Flush-pin gauges usually consist of a base or holder of some sort in which one or more pins are inserted so as to form a sliding fit in their bearings. The pins are made of correct length for gauging a given surface, the limit being determined by noting the amount of projection of the end of the pin beyond the end of the gauge itself.

As an example, let us take the flush-pin depth-gauge shown in Figure 157. In this case, the work, A, is placed on a surface plate and the gauge is used

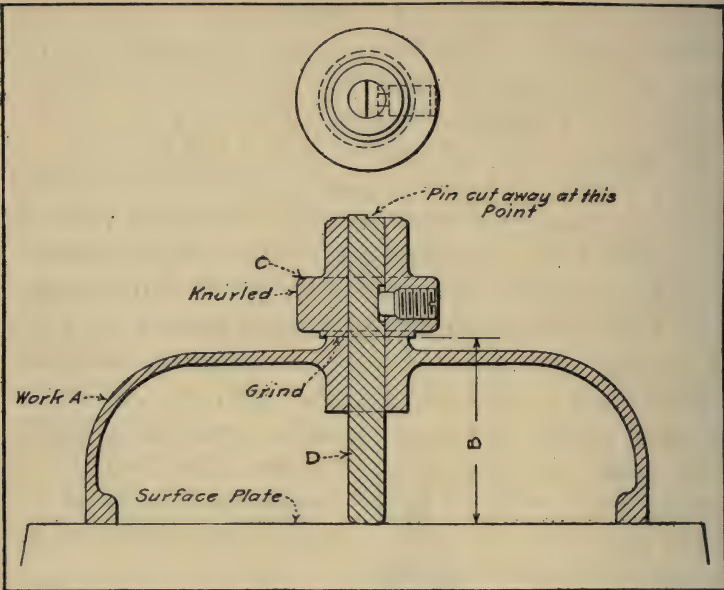

FIG. 157. FLUSH-PIN DEPTH GAUGE

to determine the correct distance, B. The gauge itself consists of a holder, C, through which the gauge pin, D, works, a small retaining pin being used to prevent the pin from falling out when not in use. The end of the gauge pin is cut away to the center line to show the amount of tolerance allowed in manufacturing the work. In using the gauge the inspector simply notes that the shoulder on the pin is lower than the finished surface on the holder and that the end of the pin does not go below the shoulder. This indicates that the work has been machined within the desired tolerance.

Gauges of this kind are not suitable for work

within very close limits. From 0.003 to 0.005 inch is as close as this type of gauge can be used to advantage. When work permits a variation of 1/64 to 1/32 inch, gauges of this kind are frequently used, but for the closer work they are by no means to be recommended. They can be adapted, however, to fine readings by using an indicator to act on the end of the pin. This indicator can either be of the dial type, applied by mounting it on a suitable holder, or it can be a simple pointer pivoted in such a way as to provide a large ratio of movement at the end of the pointer.

Referring to Figure 158, let us suppose that the push pin, A, in the upper sketch, is in contact with the work at the end, B, and that variations to 0.001 inch are to be noted. If the short end of the pointer has a fulcrum ⅛ inch from the bearing, C, on

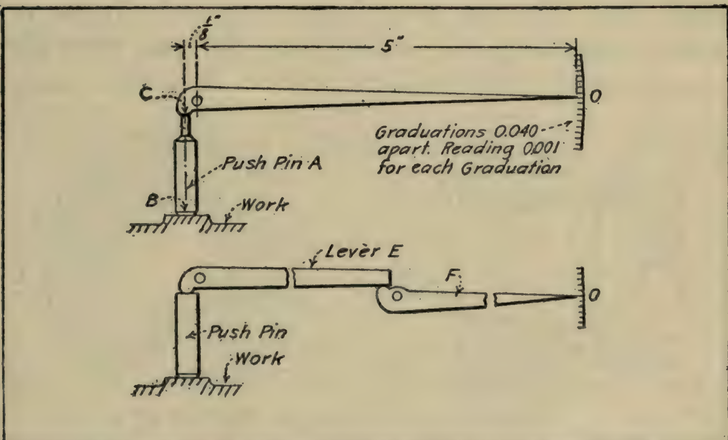

FIG. 158. FLUSH-PIN GAUGE FOR PRECISE WORK

the end of the pin, and the pointer is five inches long, then the ratio of multiplication will be as ⅛ is to 5 or as 1 is to 40. Therefore, if the graduations on the arm or scale are cut 0.040 inch apart, a variation of the pointer on one of these divisions will indicate 0.001-inch variation on the push pin.

Application of this principle can be made to many forms of gauges requiring a reading closer than that given by the ordinary flush-pin type. Still closer indications can be obtained by multiplying the levers, as shown in the lower portion of the diagram. One lever, E, working on another, F, will obtain a larger ratio.

Flush-Pin Gauge for Tapered Shafts.—When a tapered shaft is close to a shoulder, as in the case shown in Figure 159, it is difficult to gauge the taper as to its position. In such cases, the flush pin, B, can be arranged so as to push the gauge on to the shaft until the pin strikes the shoulder, A, on the work, indicating the limit when the pin protrudes

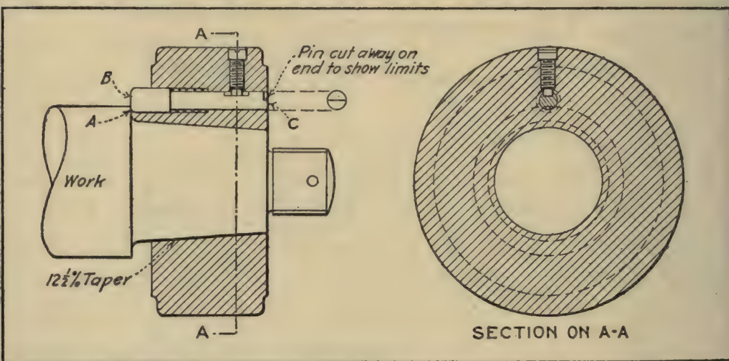

FIG. 159. FLUSH-PIN GAUGE FOR TAPERED SHAFTS

through the gauge at C. This pin is shouldered to indicate the permissible limit of error similar to that shown in Figure 157. Gauges of this kind can also be used for determining shoulder distances on straight or taper shafts.

Flush-Pin Gauge for Contours.—In some instances it is desirable to gauge one or two points with considerable accuracy and other points not nearly as closely. Take, as an example, the work shown in Figure 160. In this case, the length of the work

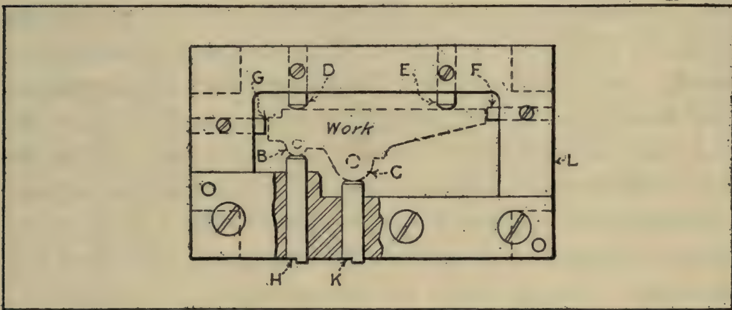

FIG. 160. FLUSH-PIN GAUGE FOR CONTOURS

between the points F and G, is not of the greatest importance, but the irregular portions at B and C must not be above a certain dimension and can be permitted to be under the dimension by 0.005 to 0.010 inch. The gauge in this case consists of a block, L, on which the pins, G, F, D, and E, are carefully set and against which the piece locates. Two flush pins, at H and K, are cut away on the end to show the amount of the tolerance permitted. It will be seen, then, that as the work is placed in the gauging

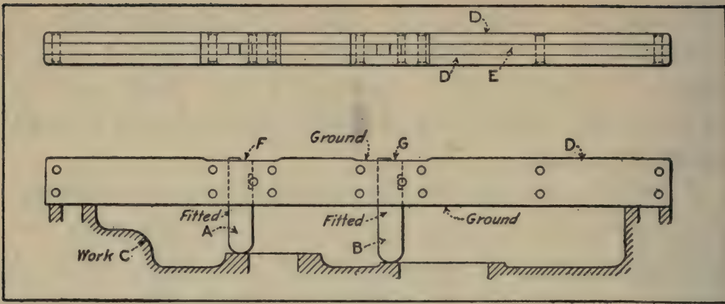

FIG. 161. DOUBLE FLUSH-PIN GAUGE

fixture these two pins, H and K,, can be moved up against the points B and C, and the inspector can easily determine whether the projection of the end of the flush pin is too great or not. In this way the desired contour of the work can be kept within the required limit. Applications of this principle may be made to many other kinds of work where it is necessary to keep a certain portion within a specified tolerance.

Flush-Pin Depth-Gauge for Indicating Two Surfaces Simultaneously.—Another type of flush-pin gauge for use on two surfaces at the same time is shown in Figure 161. This gauge is made up somewhat differently from the others, as the pins are made of flat stock and the holder is composed of two side pieces, with fillers between them, the two side pieces, D, and the fillers, E, being riveted together as indicated. The pins, A and B, indicate different depths on the fly-wheel casting, C, and the limits are shown by the shoulders on the pins, as indicated at F and G.

Where the work is large, as indicated in the illustration, a gauge of this kind may be preferred to one made of a solid piece of bar stock with holes drilled and reamed for the pins. It is somewhat lighter in construction and, although no cheaper to manufacture, it is a trifle more convenient to handle. Its operation is similar to the flush-pin gauges previously described.

In making a gauge of this kind, the various parts are hardened and are lapped to a finish. Suitable retaining pins are inserted so that the gauge pins will not be lost when the instrument is not in use.

Indicator Gauge for Testing Alignment of Connecting-Rod Bearings.—The parallelism and alignment of the connecting-rod bearings of an automobile motor is exceedingly important. It is not enough to know that the alignment of the bearings may be incorrect, but the amount and direction of variation must also be known. In order to determine these two points it is necessary to use a gauge based on the indicating principle.

An excellent type of gauge for this purpose is shown in Figure 162. The connecting rod, A, has been previously finished in all of its dimensions, and is supposed to be correct and ready for the final inspection. Previous to placing the work in the gauge, it is fitted with the special pins, B and C, hardened and ground to size, and fitting closely in the bearings at each end of the connecting rod. After the work has been supplied with these two pieces it is placed in the fixture, T, in such manner that the large end of the connecting rod lies between the finished

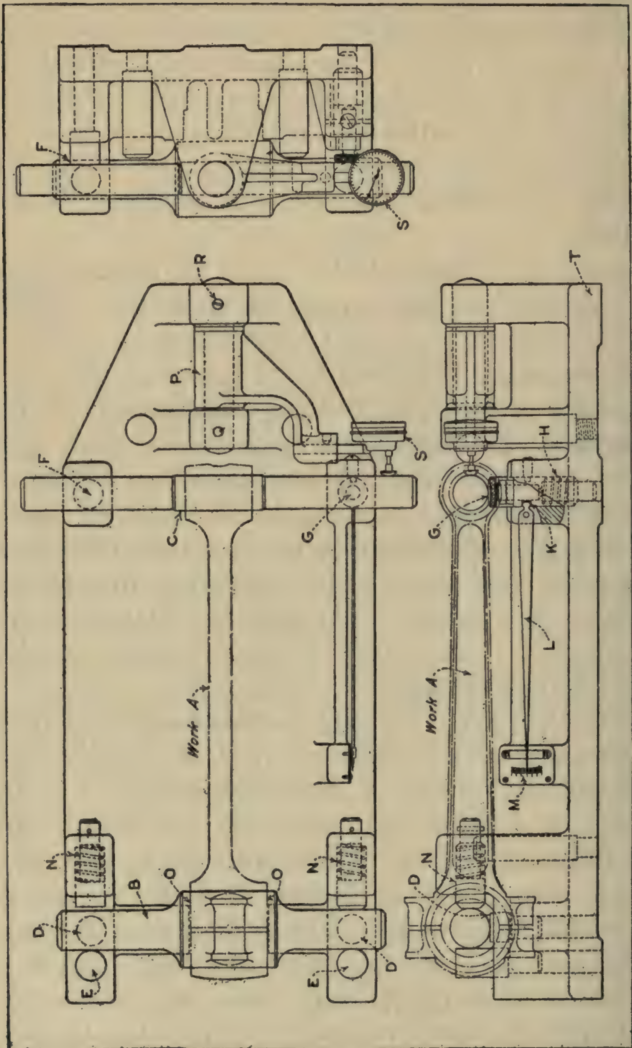

FIG. 162. INDICATING GAUGE FOR TESTING ALIGNMENT

surfaces, O, on the fixtures and the pins at B and C rest on the hardened pins, D and F, at the large and small ends of the fixture respectively. When the work is placed in position the spring pins, N, hold it firmly against the hardened pins, E, the pins, N, being carefully adjusted so as to be perpendicular to the center line of the work.

At the smaller end of the piece there is a fixed pin, F, and, on the opposite side, a pin, G, with an adjustable knurled head and supported by the coil spring, H, in the body of the fixture. One side of the spring pin is slotted at K to receive the end of the indicator, L. This indicator works on a scale, M, reading to .001 inch. It can be seen, therefore, that any variation in alignment of the connecting-rod bearings will be indicated by this pointer if the holes are not parallel in the direction indicated.

Assuming that a discrepancy has been found in the alignment, a suitable clamp can be placed on the piece while it is still in the fixture and it can be twisted until the alignment is correct. Having straightened out the alignment in this direction, it is then necessary to gauge the work in another position. For this purpose the arm, P, bearing a dial indicator, S, is mounted in bearings, Q and R, these bearings being put on a line with the center line of the work. An indication of the parallelism of the shaft, C, with that of the other end, B, can easily be determined by swinging the indicating gauge, S, from one side to the other of the shaft, C, and noting whether there is any variation in the reading of the dial when this is done. The indicator should read

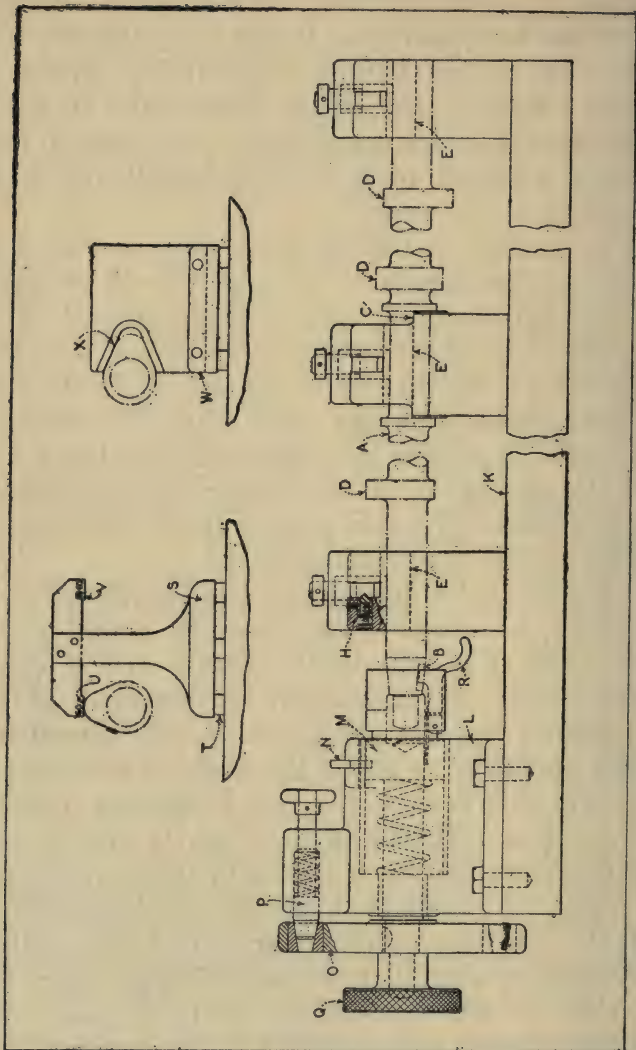

FIG. 163. ELEVATION OF INDICATING GAUGE FOR AN AUTOMOBILE CAM SHAFT

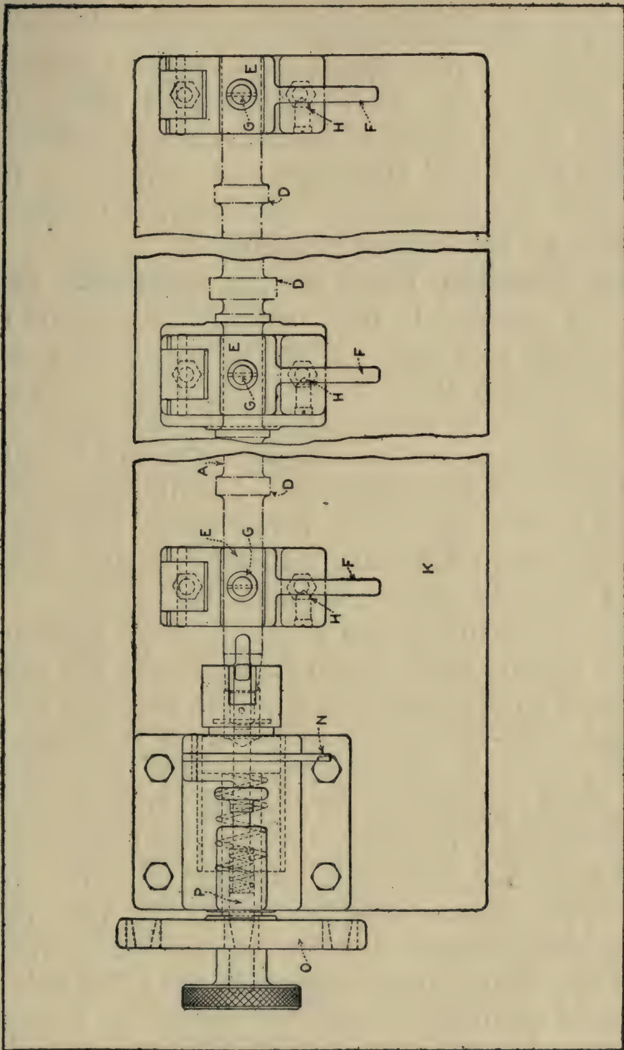

FIG. 163-A. PLAN OF INDICATING GAUGE FOR AN AUTOMOBILE CAM SHAFT

the same on each side of the shaft if it is perfectly parallel with the other end.

Applications of this type of gauge may be made to many kinds of work. It is possible to use either the dial indicator, as shown in this instance, or multiplying levers to indicate the amount of variation in the work. This particular gauge was designed by me on some work for the Russian government.

Special Indicating Gauge for an Automobile Cam Shaft.—An automobile part requiring great care in gauging is the cam shaft. A special indicating gauge designed for such use is shown in elevation in Figure 163 and in plan in Figure 163-A. In this work the shape of the cam and the amount of throw are the important points to be inspected. Usually the amount of throw of the cam is not permitted to vary more than 0.003 inch; some manufacturers hold their work within tolerances even closer than this.

In the cam shaft, shown at A, the cams indicated at D, D, D, have been forged integral with the shaft and ground to the desired shape. An essential point connected with the form and throw of the cams is their location with respect to each other and also in relation to the keyway on the tapered end of the shaft at B. It follows, therefore, that the work should be located from this keyway in gauging the cam. The fixture itself consists of a base plate, K, which has been carefully scraped to a fine finish on the surface. On this base plate three bearings, E, are set, which fit the outside diameter of the cam shaft. In gauging the work the shaft is laid in these three bearings and swinging clamps are pulled down on top of the shaft

by means of the handles shown at F. As these handles are pulled down, the detent pins, H, snap into place in a conical hole in the side of the lever, and the spring plungers in the center of the swinging clamps, as shown at G, bear down on the cam shaft and hold it firmly in place in the bearings, E. Although these spring pins hold the cam shaft firmly in place they do not prevent its rotation. After the piece has been set into place, the finger lever, R, is pulled down until the work can be revolved sufficiently to permit the locater to enter the keyway at B. The work is now set ready for gauging.

Let us assume that the work has been placed in position and that everything is ready to indicate the piece. It will be noted that the block, L, is fastened to the bed plate of the fixture and that the finger lever, R, is contained in a sliding cylindrical piece held in position by an internal spring. At the end of the shaft, M (which works in a hardened bushing on the inside of the block, L), a dial plate, O, is keyed in the correct relation to the finger lever and keyway at R and B. This dial plate contains four tapered bushings in proper relation to the keyway, B, and the work can be indexed by pulling out the taper pin, P, and turning the knurled hand-wheel, Q, for indicating the various cams. To indicate the throw of the cam, a special gauge—set on the stand, S, and having three feet of hardened steel, as shown at T, and an upper arm with indicating points at U and V for the "go" and "not go" limit of the throw of the cam—can be slid along the surface of the plate until the "go" and "not go" points on the gauge come in con-

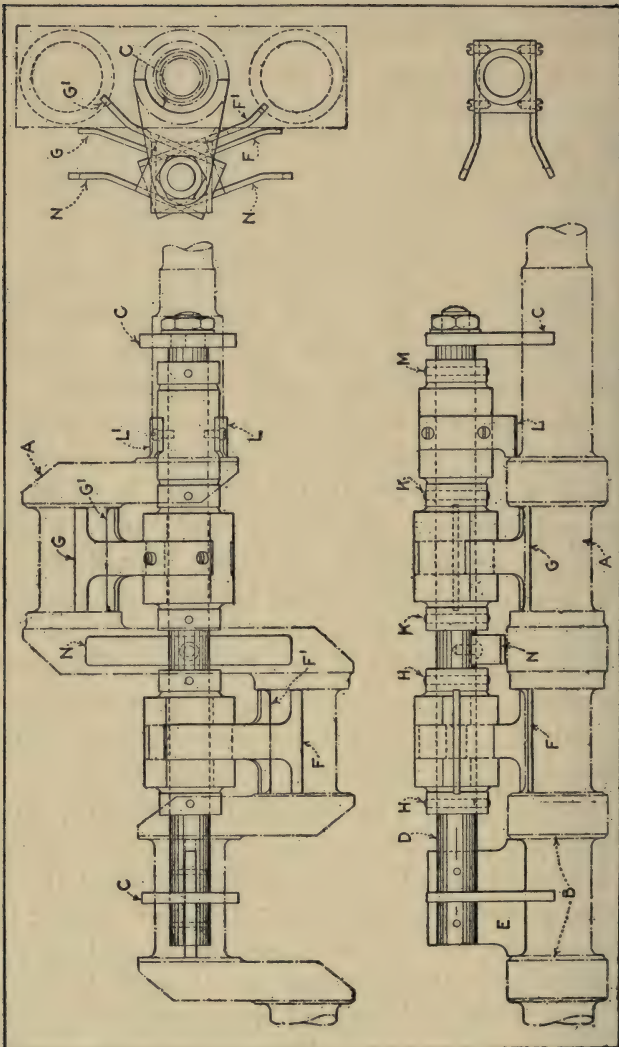

FIG. 164. FEELER GAUGE FOR AN AUTOMOBILE CRANK SHAFT

tact with the cam, thus determining whether the throw is within the desired limits or not. After these points have been determined, the indicating dial is revolved and the next cam in rotation is similarly tested.

The contour or shape of the cam is gauged by means of the block, W, which has a steel plate at X, formed to the coutour of the cam. It is obvious that this gauge is also moved along on the surface of the plate until it comes in contact with the cam so that a comparison can be easily made by the inspector.

After the shaft has been completely tested, the entire mechanism of the indexing head is pulled away from the tapered end of the shaft until the lever, M, drops down into the recess on the shaft prepared for it. This holds the mechanism far enough back so that the cam shaft can be removed without difficulty. A gauge of this kind is somewhat expensive, but the results obtained by its use are most excellent.

Feeler Gauge for an Automobile Crank Shaft.—A limit gauge, rather peculiar in its character as it is not really an indicating gauge and yet can be depended upon to hold the work within the prescribed limits of accuracy, is the crank shaft gauge shown in Figure 164. This instrument is used to determine the widths of the various bearings on the crank shaft and their relations to each other. One of the features of this gauge is that it can be used on the work while in process—it is not necessary to wait until after the crank shaft has been removed from the machine before testing it for accuracy.

The gauge itself consists of a single hardened and

ground shaft, D, having at one end a templet plate, E, which fits the center bearing of the crank shaft and is prevented from moving sideways by means of the plate, C, which is cut out to fit the bearing, as clearly shown in the end view. The other end of the gauge is also provided with a plate, cut out in like manner so that the operator may steady the gauge on the work and that it may have a correct location in relation to the axis of the work. In order to prevent the gauge from falling over sideways while the various bearings are being tested, a piece of sheet steel, M, is fastened to the shaft as indicated.

Let it be assumed that the inspector is ready to test the crank shaft and that the gauge has been placed in position. It will be seen that the bushings lying between the spacing collars H and K, have each two plates or fingers, F and F^1 and G and G^1, located one on each side of the bushings. Also the bushing at the end of the crank shaft and between the collars K and M has also a pair of feelers, L and L^1. In testing the work, the feelers at these various points are swung by the operator's fingers between the bearings. If the first feeler goes through without difficulty and the second does not, the inspector is ready to pass the work. After one end of the crank shaft has been tested the gauge is reversed and the other end is tested in a like manner, using the center bearing as the gauging point in each instance. After the crank shaft has been gauged in this way, it is absolutely certain that all the crank pins and bearings are in correct relation to each other within the prescribed limits.

Although this type of gauge is somewhat out of the ordinary, it has proved successful in this kind of work. It is obvious that the greatest care must be used in making the instrument so that the various parts may have no more freedom than is absolutely necessary.

Electrical Contact Gauge for Cams.—The use of electrical contact for determining variations within certain limits is well shown in Figure 165. Here, the

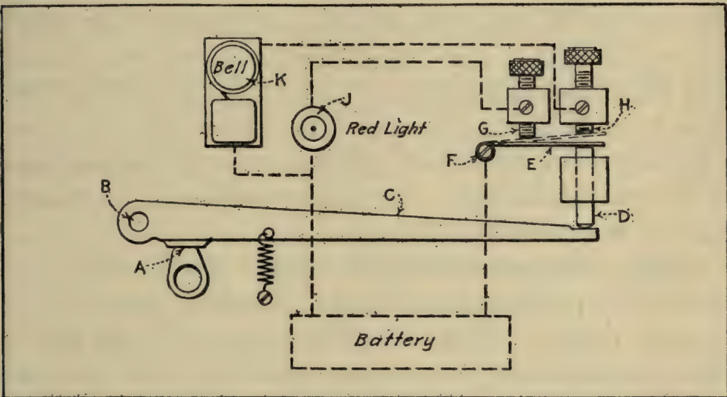

FIG. 165. ELECTRICAL CONTACT GAUGE

work, A, which is to be tested, is a cam, the throw of which must be held within certain limits as in previous instances. In this case, however, the cams are not on a shaft, but are separate and can be handled on a much smaller and simpler type of fixture.

The work, A, is placed on a stud (not shown), the stud being located in the fixture plate. The gauge is so arranged that if the throw of the cam is correct, a red light will show at J; while if the throw

of the cam is too great, the bell, K, will ring. A reference to the illustration will show that a battery is connected with the screw, F, and through it to the tempered spring, E. A multiplying lever, C, is pivoted at B, and acts on the push pin, D, which in turn pushes up the flat spring, E, until it is in contact with the adjustable screw, G. This completes an electrical circuit through the wiring indicated by the dotted line, and lights the red light at J. If the throw of the cam is too great, the push pin, D, forces the spring, E, up further until it touches the other screw, H, which also completes an electrical circuit and rings the bell at K. It must be understood that this is only a diagramatic illustration of the principles applied, and that various applications suitable to the particular piece of work which is to be gauged can be conveniently made.

Profile Inspection Gauge.—On certain classes of work the profile of the piece must be kept within certain limits. It is not always possible or convenient to make up a receiver gauge for this purpose and even when one is used, the results obtained do not show up the variations markedly enough.

The use of the ordinate principle can be employed, as shown in the Figure 166, in a case of this kind. This system of gauging leaves nothing to be desired where it is needful to inspect for accuracy and to determine, at the same time, the variation in the contour of the work. This gauge consists, first, of a surface plate, A, which has been carefully scraped to a plain surface. On this plate a master-gauge piece, X, is placed and fastened securely in position, and is

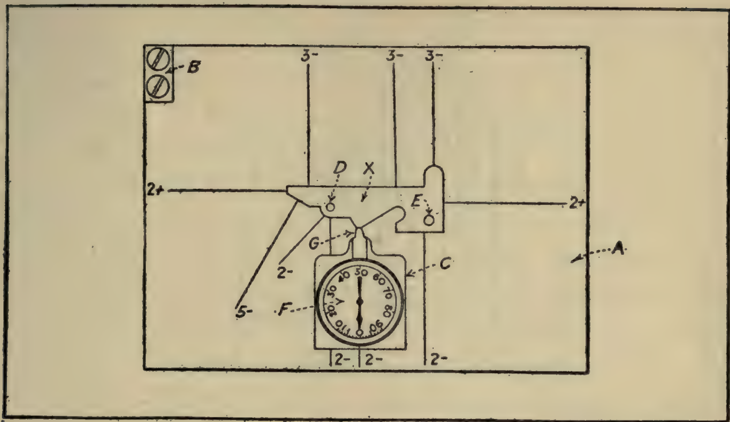

FIG. 166. PROFILE INSPECTION GAUGE

furnished with two dowels, D and E, on which the piece to be gauged is located. A dial indicator, F, is mounted on a special block, C, and has a hardened point, G, directly under the gauge or indicator point on the dial. Before using the gauge it is moved over to the plate, B, and the dial is set at 0, the pin then being in contact with the perpendicular side of the block, B. After the gauge point has once been set in line and the indicator turned around so that the dial around the work to the various lines shown until the lines on the indicator correspond to the lines on the base plate, A. A reading can then be taken, and if the pointer does not show variation greater than that marked on the plate at the point where the reading is being taken, it may be safely assumed that the work is within the limits prescribed. The system of gauging can be applied to many forms of work which require a careful inspection of the contour and where

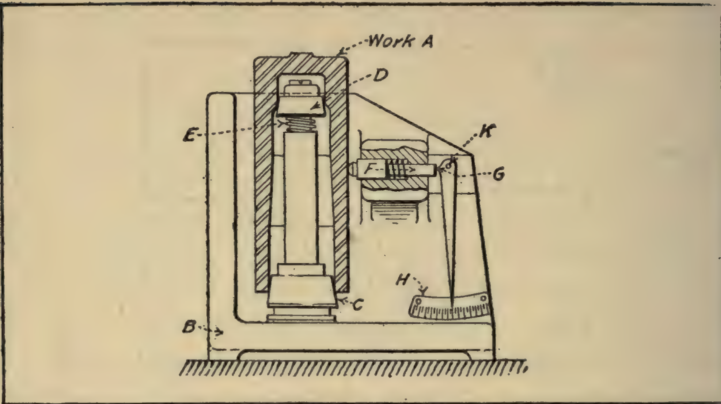

FIG. 167. GAUGE FOR DETERMINING CONCENTRICITY

it is necessary to know how much variation there is at various points.

Concentricity Indicating Gauge for High-Explosive Shells.—In the inspection of high-explosive shells the concentricity of the exterior surface with the inside is important. In order to determine this rapidly and without difficulty, the gauge shown in Figure 167 was designed. This is a very simple type of indicator gauge and the principles upon which it is based are applicable to many other forms. The work, A, is placed on the fixture and is located by the lower end, which is tapered, at C and also by means of the sliding tapered bushing at D. This latter bushing is supported by a light spring, E, in order to make sure that there is a contact on both tapered bushings. If this were not so arranged, it might be that the work would be placed in position and located only on one end, which would cause a wobble in the

work when indicating. The standard on which these two bushings are located may be revolved in the fixture, and the work can be turned around freely by hand when in position. As the work is revolved, the plunger, F, which is spring controlled, bears against the outside of the casing and operates the indicating pointer, pivoted at K, and has a fulcrum at G. The lower end of the pointer moves along the arc of the graduated scale, H, thus showing variations in the concentricity of the work according to the amount of multiplication in the lever. In the case noted, the multiplication is 20 to 1, as this is amply sufficient to show variations in the concentricity of the work. The principle shown in this fixture can be used with an indicating dial; it is simply necessary to mount the dial indicator in some way on the fixture so that the push pin, F, will operate against it.

Johansson Gauges.—Any description of gauging systems which does not include some mention of the testing blocks originated by Mr. C. E. Johansson would be incomplete, although the system is well known throughout the country. Briefly stated Johansson standard gauges are parallel-lapped blocks, in which the two opposite sides of each block are perfectly parallel and the distance between them is equal to the size marked upon the block. These blocks are furnished in a number of sizes, so that any dimension up to the limit of the various blocks can be obtained by placing the surfaces of blocks marked to the sizes required against each other in such close contact that a measurement across the blocks will give absolutely the dimension required.

All Johansson standard-gauge blocks up to 6 inches are guaranteed to have no greater error than 0.00001 inch, that is 1/100,000 part of an inch. They were originally intended for use in the tool room only for the quick and accurate laying out and checking of jigs and fixtures, but their applications have become better known until now they are used for checking many varieties of work. The gauge blocks are made up in a number of sets to suit various requirements. With their standard holders for making up a number of blocks to a required dimension, they can be considered as a valuable adjunct to the tool room for checking dimensions, limits, gauges, and other work requiring extreme accuracy. A lengthy description of the Johansson system of gauging is unnecessary, but it is safe to say that no manufacturer who is engaged in the production of interchangeable work or any kind of work requiring extreme accuracy can afford to be without a set of these gauging blocks.

CHAPTER XXV

PATTERNS

The Use of Patterns.—A casting which is to be machined must be made by a pattern. The simplest form of a pattern may be identical in shape and size with the piece which is to be made; but, on the other hand, the pattern may differ quite widely, depending upon the construction of the piece, the number of holes in it, and whether it has ribs or protuberances of different kinds which may necessitate that it be made up to provide for the use of core boxes or core prints. Speaking generally a pattern is a form which can be laid in damp sand or some other plastic material such that when molten metal is poured into the mold the desired shape will be reproduced in metal. Usually the outside of a pattern has the general form of the piece which is to be moulded and differs from that piece only in the various pieces called core prints, which stick out from the patterns here and there according to the requirements of the work.

Patterns are usually made of wood, but they may also be made of metal, rubber, plaster, and occasionally of other materials. Regardless of the material used, however, the pattern itself does not differ in form nor is the result obtained greatly different.

In work requiring a great number of pieces of the same kind, metal patterns are more commonly used, as they are more durable and will stand handling much better than the wooden. For work that is comparatively small and involving a number of pieces of the same kind, a number of small metal patterns can be made up and arranged in the mold about a "gate," so that a great many castings can be made at one time in the one mold.

Wooden patterns and metal patterns are made in practically the same way, the difference being that the metal pattern must be cut and worked into shape with different tools than those used on the wooden pattern as it is obvious that metal cannot be cut properly with wood-working tools. Frequently, in the making of a metal pattern, a wood pattern is first made which is a little larger than the work is to be, so as to allow for finishing and also for shrinkage, and a casting is made from it in some kind of metal which can be conveniently worked. This casting is then used for the metal pattern after the pattern maker has worked it up to the desired size.

Form of Pattern.—In making a casting, the first thing for the pattern maker to determine is just how his work is to be molded. The important point in this connection is the withdrawal of the pattern from the sand which has been rammed around it. If the pattern is simple in character, no great difficulty should be experienced in this matter; but if the work has a number of bosses or lugs and is of a peculiar shape, the matter of molding must be carefully considered by the pattern maker in the making up of

his patterns. Obviously, it is necessary for the pattern to be made in such a way that the molder can withdraw it from the sand without disturbing the impression which the pattern has created in the sand. The pattern maker must always possess foresight enough to make provision for removing the pattern from the mold after the sand has been packed around it.

Method of Molding.—The best way to understand thoroughly just how a pattern is molded is to describe the process in connection with a simple pattern, such as that shown in Figure 168. In the first place it must be recalled that the fine sand used for molding is moistened slightly so that it will hold together in the flasks into which it is pounded or rammed around the pattern. These flasks are of various kinds, but in their simplest form they are boxes open at top and bottom and made either of wood or metal. The boxes are provided with lugs on the sides through which dowel pins may be passed so that two flasks can be put together in such a way that they always bear the same relation to each other. They can then be separated and replaced at will, with the assurance that the parts of the mold in the sand will correspond. The upper half of the flask is the "cope" and the lower half is the "drag" or "nowel."

It will be noted that the pattern shown at A in Figure 168 is what may be called a "solid" or "one piece" pattern and that it has no core in it. It may be said of this pattern, therefore, that it leaves its own core in the sand and does not require anything special in its construction. This particular piece is

an exact model of the casting which it will produce and is a good example of the simplest form of molding. The shape of this particular piece is such that the angles on both outside and inside give an excellent draft, permitting the work to be removed without disturbing the sand in any degree. When the

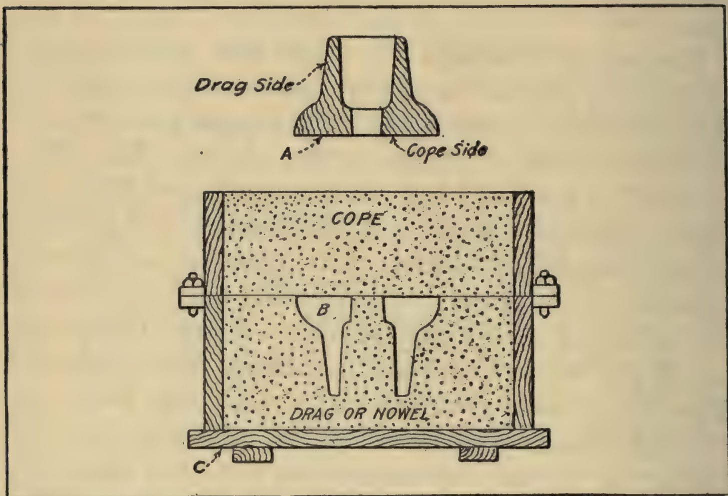

FIG. 168. METHOD OF MOLDING A SIMPLE PATTERN

molder prepares to mold this pattern he takes a large flat board, such as that shown at C, and places it on his bench. On this board he places the pattern, A, with the large side down; over it he puts the drag portion of the flask. He then sifts or "riddles" fine sand all over the surface of the pattern and rams it tightly. After this has been done, he fills the remainder of the flask with coarse sand which is also rammed tightly, just filling the box flush to the top.

The entire box is then turned over until the cope side comes upward, as shown in the illustration. The exposed surface is now sifted or covered lightly with parting sand—that is, white beach or river sand. This is done to prevent the cope side of the flask from sticking to the drag. The cope side is then placed in position over the drag and the entire box filled with coarse sand, rammed in. Cope and drag are then separated, the pattern carefully removed from the mold, the cope replaced, and the flask is ready for molding or is set aside until required.

Cores and Core Boxes.—If the casting to be made requires a hole in it and, because of the shape of the pattern, it is not possible to place the pattern in the mold (as in the instance noted) in such a way as to leave a pyramid or conical portion of sand in the mold that will prevent the metal from flowing into that part and thus leave a hole in the resulting casting, it will be necessary to make a separate "core." For example, in Figure 169 a separate core is necessary on account of the shoulder on the inside of the work. This requires that a core box be made specially for it.

Cores may be made from metal, dry sand, or green sand. The kind illustrated in Figure 168 is the green sand core and is made at the same time that the mold is made. There are occasional instances when a green sand core can be made up separately and placed in the mold, but these cases are rather rare and need not be considered here. Metal cores are chiefly used in brass work or other work in which considerable accuracy is required. They are not used

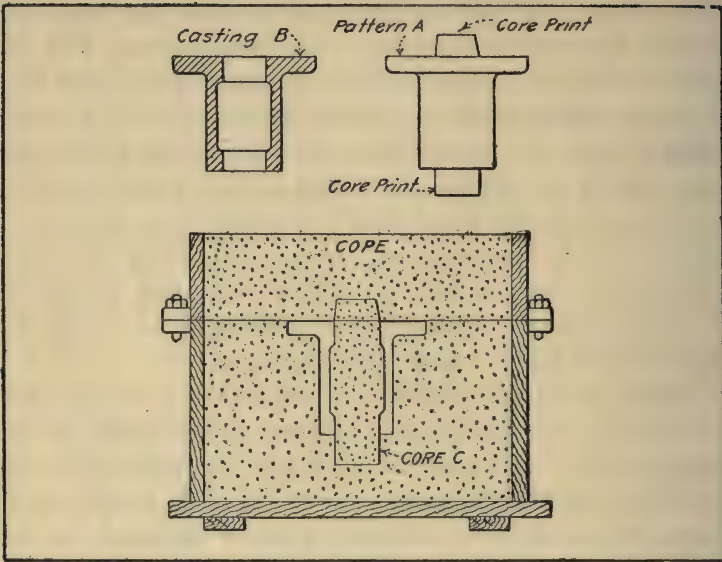

FIG. 169. MOLD AND PATTERN SHOWING USE OF BAKED CORE

in molding cast iron. The most common form is the dry sand core. This is made from a fairly coarse sand mixed with some binder material to hold it together and then baked until perfectly hard and thoroughly dry.

Dry sand cores are molded in core boxes made up to the shape and size desired. Core boxes are usually made of wood in two or more parts, depending somewhat on the shape of the core itself. The making of core boxes for patterns is fully as important as the making of the pattern itself.

After the core box has been made, the mixture of sand, with the binder thoroughly incorporated in it, is placed in the core box until it is filled completely.

It must be remembered that the core in the box is stable, but when removed it is somewhat delicate. In some cases, then, it is necessary to reinforce the core sand by means of rods or bars of different shapes to conform to the size of the core and its contour. After the core box has been filled, the core is removed, laid on a plate, and placed in the oven in order to dry out. It is then ready for use in the mold, having first been given a coating of blacking with a composition of plumbago or graphite, in order that the molten metal may not stick to the core.

Referring to the pattern, A, Figure 169, a core print, as it is termed, is seen at each end. There is a taper on the upper of these prints, for it is on the cope side of the mold and the cope could not readily be removed unless this part of the print were made tapering. Occasionally the tapered end of the core print is removable, so as to make it easier for the molder to do his work. Otherwise the molder will bore a hole in his molding board to accommodate this end of the print when ramming up the pattern.

Referring to the casting, B, shown in the same illustration, an inside recess is seen of such a form that it would be impossible to mold the work from a pattern without a separate core. Therefore a core box is made up to give the form indicated at C, and after the pattern A has been rammed in the mold, this core C is inserted prior to the molding operation as indicated in the illustration. When the metal is poured into the mold it will flow all around this core and into the depression left by the pattern form, thus producing the desired shape. After the iron has cooled

and the mold is dumped, the core, being of a fragile nature, can easily be broken up and knocked out of the casting, which is then left in the condition shown at B.

Two-Part Pattern and Method of Molding.—The casting, A, Figure 170, is seen to have flanges at each end of such form that the casting could not be molded in the same manner as that shown by Figure 169. In work of this kind the better method is to make up a two-part pattern, as shown at B, and prepare to mold the work as indicated in the illustration. It will be noted that this two-part pattern is separated on the center line and that there is a dowel pin, C, at each end of the pattern so that the two parts can be placed together in their correct relation at all times.

In molding, one-half of the pattern is laid down on the molding board and the drag portion of the mold is rammed up around it. The mold is then turned over and the other half of the pattern laid on to its fellow, after which the cope side of the mold can be rammed. After lifting out the pattern and placing the core in position as noted, the work is ready for molding.

Occasionally in cheap pattern work it may not be desirable to make a two-part pattern. When this is the case, the method shown in the lower part of the illustration can be used. In this, the pattern is made in one piece, and the molder lays the pattern down on his molding board and rams up the mold in the drag portion. He then turns over the drag, as indicated in the illustration, cuts down the slope, D,

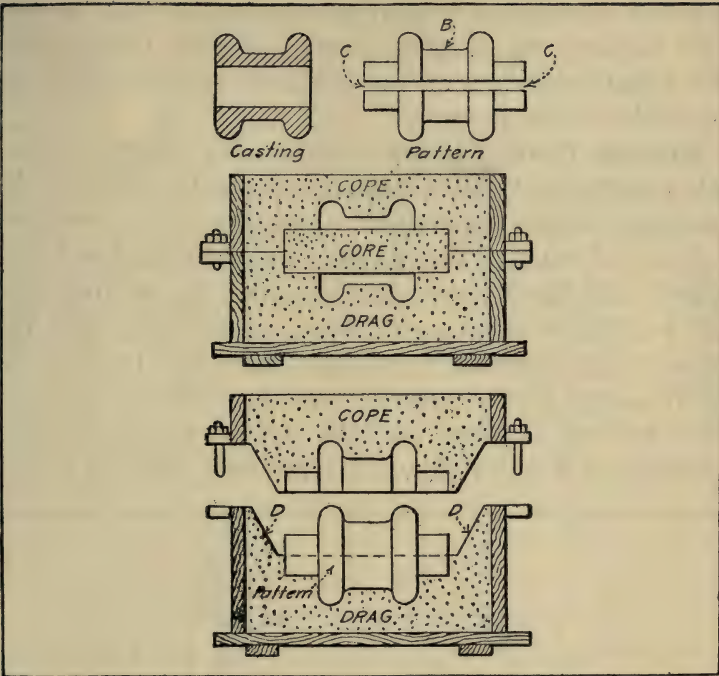

FIG. 170. TWO METHODS OF MOLDING A PATTERN WITH FLANGES
Upper figure shows the split-pattern method. Lower shows solid pattern.

with his molding tool, and removes the sand down to the center line of the pattern, leaving it all clear and clean. After sifting parting sand on the drag portion of the mold, he places the cope flask in position and rams this up also until it takes the form shown in the illustration. The cope can then be lifted carefully off so as not to disturb the sand which is hanging below it, and the pattern can be removed and the core inserted as in the previous instance. This

method of molding is seldom used unless only one or two castings are desired from a certain pattern, for too great a portion of the molder's time is taken up than the work warrants.

Circular Cover Pattern.—Figure 171 shows a somewhat different type of pattern. Here the work to be produced from the pattern is shown at A, and the method of molding the piece is indicated in the lower portion of the figure. In this case the parting line of the pattern is at C; there is a projection into the cope of the pattern itself, and also the portion, B, of the cope extends down into the pattern. To use this pattern it must be laid down on the molding board and a suitable recess provided for the flange

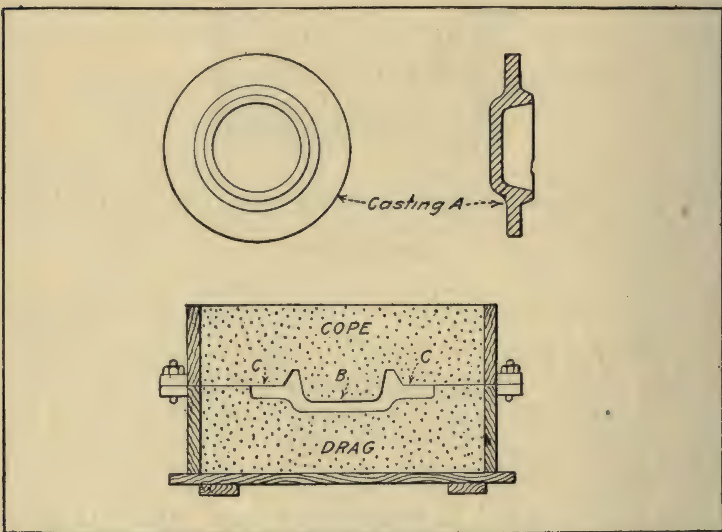

FIG. 171. CIRCULAR COVER PATTERN SHOWING PART OF THE MOLD IN THE COPE SIDE

portion so that the parting line, C, will lie flat on the board. The sand is then rammed around the pattern, after which the drag is turned over in the usual way and dusted with parting sand. The cope is now placed in position and rammed up, the sand being forced down into the portion B, and lifting out as the cope is removed so that the part, B, remains hanging from the cope side of the mold.

Pattern Requiring a Three-Part Flask.—In some instances it is necessary to mold a certain kind of pattern in a flask containing more than two parts. An instance of this kind is shown in Figure 172 where the work, A, is a casting having four ribs and a flange at each end. It is apparent that it would not be possible to ram sand all around the pattern and then be able to remove it from the sand without disturbing the mold. The pattern is made up, therefore, in the form shown at B, the usual core print being applied and the pattern itself being arranged so that it can be separated along the line X-Y.

The process in molding this pattern is as follows: The large flange is placed on the molding board, the "cheek" of the three-part flask is first rammed up as far as the separation of the pattern X-Y, the cope being then placed in position and rammed in turn. Both cope and cheek are then turned over together on to the molding board and the drag side is completed. In removing the pattern, one part is drawn from the large flange side and the other from the small flange side. The core can then be placed in position in the usual way, and the mold is ready for pouring.

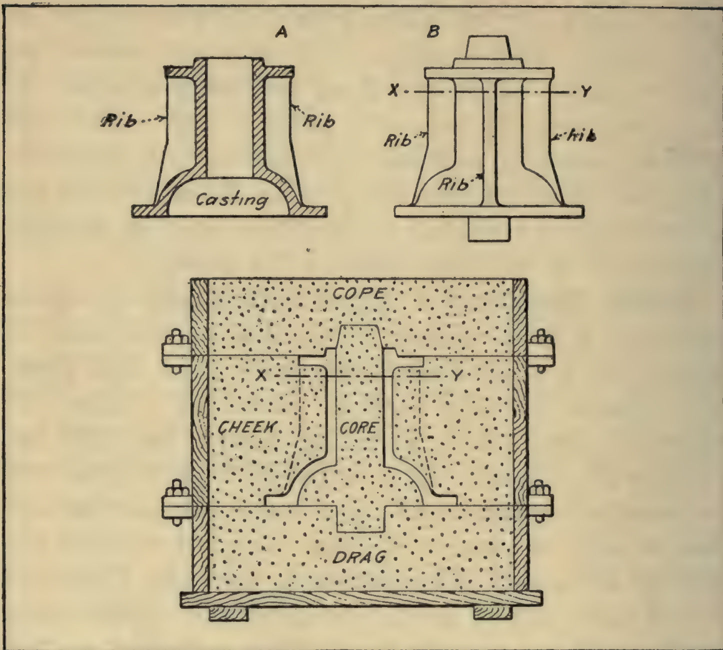

FIG. 172. EXAMPLE OF MOLDING A FLANGED AND RIBBED PATTERN IN A THREE-PART FLASK

Other Forms of Patterns.—It is not necessary to present a lengthy discussion of the various forms of patterns, but several other kinds may be mentioned in a general way in order to make the subject a little clearer. The matter of loose pieces is one which occasionally gives the pattern maker and molder more or less trouble. For instance, in making a casting that has a number of lugs or bosses on it of such a kind that they could not be readily removed from the molds, the pieces are frequently made loose with a pin in them to permit their ready removal. In molding

such a piece of work the pins are removed from the loose pieces before the pattern is taken out of the mold; the pattern can then be removed without disturbing the loose pieces which can be taken out by the molder's hands afterwards.

The type of patterns known as "sweep" patterns should also be mentioned. These are used for circular work when a very cheap pattern is desired. They can be made for almost any kind of cylindrical ring, and if made in sectional form to take up a certain portion of the mold desired, this part of the pattern can be attached to a radius stick pivoted at the center of the mold and a part of the mold rammed up at a time. After one section of the mold has been prepared in this way, the sweep can be moved around to another section which is treated in like manner.

Skeleton patterns may also be used in a somewhat similar way. But attention should be called to the fact that each of these types just mentioned is used for the purpose of economy where only a very few castings are to be made from any one pattern. The skeleton pattern is used in place of a complete pattern, but its principal claim to distinction is that it can be made up cheaply for cylindrical work. While the pattern maker saves considerable time in making either a skeleton pattern or a sweep, the molder, however, is required to spend very much more time in making up the molds than he would do if he were provided with the proper kind of pattern.

Tools for Pattern Making.—The tools used in pattern making are much the same as those used by any carpenter, except that a number of varieties of spe-

cial tools are required, such as those used by the cabinet-maker and wood-carver. A number of special machines are in use in the pattern shop in order to facilitate the work of pattern-making. These include such special machines as the core-box machine, which is specially designed to assist in cutting out the inside work in a core-box, and also sand-papering machines of the disc type with adjustable tables to permit them to be set to different angles for the greater convenience of the pattern maker. Other tools used in the pattern shop are the circular saw, the band saw, the hand jointer or buzz planer, the mortiser, and the shaving machine. Special pattern-maker's vises might also be mentioned, which are so constructed as to hold the work in any desired position without injury. The tool-maker's engine lathe is also found in the pattern shop and is largely used. In addition to all the above, each pattern maker has his own private supply of hand tools, most of which have been made up by himself for certain kinds of work which has been out of the ordinary. Aside from these, the cabinet-maker's or carpenter's kit of tools would represent general usage.

CHAPTER XXVI

PATTERN RECORDS AND STORAGE

Desirability of Pattern Records.—Keeping patterns after they are made, in a safe and readily accessible place, is a matter that has deservedly received considerable attention in late years. Formerly, the boss pattern-maker had a system of his own; he located any desired pattern in from ten minutes to three or four days, depending on his memory and the amount of time he could spare in looking it up.

The boss pattern-maker frequently was, and still is, a man who had held the position for a number of years and who might be expected to know what a given pattern looked like and where it was likely to be found. Memory is a poor thing to depend on, however, for locating anything, and the results from the sudden death, illness, or resignation of the man having this store of knowledge can well be imagined. Consider the amount of time consumed by the boss pattern-maker under ordinary circumstances in finding a given pattern and estimate the cost of finding the pattern under these conditions.

However, it is gratifying to note the progress made in this respect among present-day manufacturers. Nearly all of them now-a-days have a well-ventilated, light, and convenient pattern-storage

building, with suitable racks or compartments in which the patterns are kept. In former times it happened not infrequently that the loft (if there happened to be one above the pattern shop) was utilized for storage, and it took a man with a searchlight and a pair of good eyes some time to find what he wanted.

Quality of Patterns.—Before going into the matter of pattern storage and records, I should like to say a few words in regard to economy in the construction of patterns; for it is always a good plan to consider other things in addition to the first cost of a pattern, and there are many factors affecting the construction.

It is obvious that the number of pieces to be made from a given pattern is an essential factor in determining the character of the pattern. For example, a jig or fixture pattern is usually made as cheaply as possible, for it will only be used once or twice. Any other sort of pattern for a special machine or mechanism, which will be used for only one or two castings, would therefore seem to come under the same category, but here other factors vitally affect the construction. A special machine may be designed for use in a manufacturer's own shop, or it may be sold to a customer; in either case the appearance of the finished machine must be considered, and therefore the pattern should be well filleted, with corners rounded, and finished throughout so that the castings obtained from it will be of good appearance.

Speaking generally, it is not necessary or even desirable to give patterns of this kind a high finish

with several coats of varnish. A good sandpaper finish is usually sufficient, although a coat of shellac is a very good protective covering that may preserve the pattern in better condition than if it were left without it, in the event that other castings may be wanted at a later date. These matters are generally left to the judgment of the pattern-maker when he is instructed by the foreman as to the kind of pattern wanted.

Usually in making a pattern for a single casting, the warping of the wood from which it is made and the consequent distortion arising therefrom are not taken into consideration, so that if another casting is desired at a later date, it may easily happen that the results obtained in the second case are unsatisfactory. If there is a likelihood of a pattern being used a second time, provision should be made to prevent undue warping. However, attention to this matter should not permit too great an addition to the first cost of the pattern. Judgment should be used in all cases.

Patterns which are built up in sections, with the grain of the wood running in opposite directions, are not generally desirable for single casting work on account of the first cost of the pattern; but when the shape of the work is such that there is strong likelihood of distortion, the pattern should be made substantial enough to counteract any tendencies of this kind.

For patterns which are to be used over and over again, the first cost should be a secondary consideration. A poorly built pattern will go out of shape and

become so damaged by frequent molding that it will soon need to be replaced by another. Of course, when the size of the work will permit it, and the number of castings to be made warrants the expenditure, a metal pattern is most satisfactory. The cost of a metal pattern, however, is very much greater than the cost of one made of wood, so that it is uneconomical to use metal unless a great many pieces of the same kind are to be cast from the same pattern.

In machine-tool patterns there is always a possibility of a change in design of the machine. This may make an entirely new pattern necessary, and therefore metal patterns should be rather sparingly used for work of this kind because of their expense and the likelihood of an early discard.

Economy in Combination Patterns.—In the making of pulleys or gears with spokes, which require several pieces of the same diameter but with different lengths or sizes of hubs, considerable economy can be effected by using one spider and ring pattern with loose hub pieces of different lengths and diameters. A combination of these loose hub pieces with the spider and ring will meet a number of different conditions. The spiders can also be made with a varying number of spokes and the pulley rings can be made in different widths so that a wide variety of castings can be obtained. Hubs and spiders can be so made as to be interchangeable one with another, so that with only a few complete patterns combinations of all kinds can be quickly and satisfactorily effected.

Gear Molding Machine.—Another great economy in pattern making has been the development of the gear molding. This permits a special pattern to be made in sectional form which has only one tooth space on the rim and a part of a tooth on each side, instead of an entire pattern of a gear with teeth all around it more or less accurately spaced according to the skill of the pattern maker. The gear molding machine takes the sectional pattern and molds the remainder of the teeth far more accurately than is possible in any other way.

Pattern Records.—Having considered the making of the patterns and the economies which can be put into effect in their construction, let us see how we can best take care of them after they have been made, and how we can locate them when wanted without resorting to memory. It is apparent that any record for patterns must be based on the method used in identifying any component part in the class of work being manufactured. Thus, if machine tools are being made, the system used should identify the machine by number or name, the part by number and name, and the location of the pattern in its rack in the pattern storage building. It is useful also to have the date that the pattern was made, its cost, and the weight of casting incorporated in the index, together with information regarding core boxes and a record of castings made with date of order, etc. Figure 173 shows a simple index card that is applicable in recording the patterns used in making machine tools.

In any record of this kind the cards should be filed

Machine No. 1061   Piece No. 181 B

Name of Piece Turret   Location F-21-C

Patterns 1   Core Boxes 2

Date Cast'gs Ordered	No.	Where Ordered	Weight	Price	Cost	
9-12-16	16	M. B. Co.	1682	5	84	10
1-5-17	30	M. B. Co.	3170	5½	174	35
6-14-17	25	M. B. Co.	2640	5½	145	20

FIG. 173. PATTERN STORAGE RECORD CARD

under the number of the machine itself and then numerically by piece number. A cross index is also valuable in which the parts are filed alphabetically by name, but this index need only be used when the piece number is not known.

It is evident that any kind of a pattern storage index must be arranged according to the requirements of the particular product, but adaptations of the foregoing system can be devised.

Marking the Patterns.—Every pattern should have a number fixed to it so positively that it cannot become lost or separated from the pattern itself. An aluminum plate with the number embossed on it is very excellent for this purpose, and machines adapted to the marking or stamping of these plates should form a part of every pattern shop equipment. These

machines are simple, reasonable in price, and do not get out of order easily. In addition to the number plate, the number should be painted on the pattern in case the plate should be knocked off and lost. It is also necessary to have the storage location plainly marked on the pattern, so that when it is returned from the foundry it can easily be put in its proper place without reference to the card index.

Storing the Patterns.—The actual method used in storing patterns is dependent upon the facilities provided or available for the purpose. If a building can be used for this storage, it should be equipped with steel or wooden racks—preferably steel—laid out in aisles or sections. Each section can be given a letter and each shelf a number, so that a location specified as F-21, for example, would mean Section F, Shelf 21. This can be further subdivided to provide for small patterns by a suitable box which can be placed on the shelf and also designated by a number or letter, as F-21-C, which would indicate Section F, Shelf 21, Box C.

The lighting of the pattern storage building is important. If the building can be lighted by ordinary daylight, it is an advantage; but if daylight is not available, good artificial lighting should be provided, preferably by means of portable incandescent bulbs suitably caged and having long cords to permit lights to be carried from one shelf to another as required.

Another point which should be mentioned in connection with pattern storage is that the building must be dry, since moisture is very apt to affect the glue in the patterns to such an extent that it may

cause them to fall apart and give an endless amount of trouble.

By no means the least important of the factors in connection with pattern storage is the nature of the building in which they are stored. It might be said that above all buildings in the plant, this should be as nearly fireproof as possible. One can readily imagine the havoc caused to any plant through the loss of the patterns on which the business was based. At a price, buildings and machinery can be readily replaced in fairly short order; but patterns, which are the fruits of years of development and upon each of which large sums of money, in many cases, have been expended, can only be replaced, if ever, by an equal expenditure of time and money. In other words, it is possible that the loss or destruction of the patterns through fire might result in the total failure of the business; the least effect is a more or less protracted delay in filling orders.

Many of the patterns themselves are highly inflammable; these should be individually guarded. Metal patterns, of course, suffer little danger of damage from a small fire; but in the event of the loss of the storage building by fire, even they would be damaged beyond repair. Too great stress, therefore, cannot be placed on this point, and in far too many cases it is a factor which has apparently been entirely overlooked.

CHAPTER XXVII

CARE AND STORAGE OF CRUCIBLES

Clay Crucibles.—The crucibles used for melting small quantities of metals are made either from clay or graphite. In the steel industry crucibles are used extensively, principally in the manufacture of so-called crucible steel. Their greatest use, however, is in brass foundry work, and the graphite form is much preferred to the clay on account of its greater durability.

When clay crucibles are used, a high grade clay is mixed with about 5 per cent of powdered coke and made into a stiff dough or paste by the addition of water. The mixture is then thoroughly worked or kneaded until it is of uniform consistency, after which it is forced into a mold of the desired shape by means of a plunger. The top of the crucible is then formed (after removal from the original mold) by forcing over it another die of conical shape. The formed crucibles are then allowed to dry slowly for a few days without the aid of artificial heat. After this preliminary drying they are placed near the melting furnaces for final drying out.

In the molding operation a hole is left in the bottom of the crucible, through which a pin passes to center the plunger used in forcing the clay into the

mold. This hole is left open until the crucible is placed in the furnace, and is closed by resting it on a little clay stand in the furnace and throwing a little sand into the hole. This sand fuses very quickly from the heat, effectively stopping the hole and at the same time cementing the crucible to the stand on which it rests.

The greatest care is necessary in handling clay crucibles. They must be heated very slowly, and must be re-charged while hot. While their normal cost is not high, they are easily broken and may cause a loss in metal and in damage to the furnace in which they are used far in excess of the value of the crucible.

Graphite Crucibles.—Graphite crucibles have many advantages over those made from clay, and are therefore used by a majority of manufacturers in this country. They will stand more heats and rougher handling than clay crucibles; can be tested for cracks and thickness before charging, and can be charged cold.

Prior to the war, graphite crucibles were made from German clay and water to which is added sand and Ceylon graphite. A substitute for the German clay, however, is now being used which gives exceedingly satisfactory results. The mixture of clay, water, sand, and graphite, is made up into a stiff paste which is allowed to "season" by keeping it in a damp place for several days. When the material has been properly tempered or "seasoned" it is placed in a mold upon a potter's wheel and revolved. A movable arm or profile iron spins out the material to fill the

mold, at the same time acting as a gauge to keep the walls of the crucible at the desired thickness for the purpose in hand.

After the spinning operation, the crucible is seasoned for another 24 hours at a temperature of not more than 80 degrees Fahrenheit, and is then smoothed up to its desired form ready for the final seasoning. This final seasoning is accomplished by keeping the crucibles at a temperature sufficient to drive off the hygroscopic moisture for a period of three weeks. They are then placed in an annealing oven at a temperature of 1500 degrees Fahrenheit and kept there for three days to remove all traces of moisture. This process is termed "burning". The finished crucibles are then protected by placing them inside clay molds to prevent oxidation and damage of other kinds. Before using the crucibles, however, they should be kept for a considerable time in a warm place. This final seasoning tends to toughen the crucible and give them greater durability, hence they are often kept for some time after being made. Crucible covers are generally made from the bottoms of old pots, and are treated in the same way as the crucibles themselves.

The "scaling" or flaking, which is sometimes seen in crucibles, is caused by improper annealing and seasoning. The material of which they are made is of such a nature that it absorbs moisture rapidly, unless prevented, and when the crucible is placed in the furnace in this condition the moisture is converted into steam, causing a "flaking" by blowing off pieces of the pot entirely, thus rendering it unfit for use. As

pointed out, the moisture must be driven off by a slow process of annealing and tempering in order to prevent any trouble of this kind. Crucibles which have been thoroughly dried out will seldom flake or crack when heated, and it is therefore of supreme importance to see that this preparatory work is thoroughly done.

Storage of Crucibles.—The prime requisite in the storage of crucibles is that they be kept in a warm and dry place. Where pit furnaces are used in the foundry, an excellent place for storage is just back of the battery of furnaces, where both dryness and warmth will be assured.

A special oven can be arranged which utilizes the waste heat from the furnaces, and by using dampers of suitable form the heat can be regulated to make an annealing oven of it. Whatever arrangement is made for crucible storage it is absolutely essential to provide continuous warmth, and not have an interval during which the crucibles cool off and absorb moisture.

Care in the Use of Crucibles.—An important point in connection with the care of crucibles is to prevent the graphite from burning off the outside of the pots during use. An oxidizing atmosphere will do this. Therefore when oil and gas furnaces are used for heating, a reducing flame must be kept up. A badly burned crucible is the result of directing an oxidizing flame directly upon it; such a crucible is soon ruined. Better results will be obtained by using a wider flame from burners adapted to high-pressure oil and low-pressure air; these burners are more

easily controlled and not so severe in their action as burners which are designed for low-pressure oil and high-pressure air.

In using fuels, those which have a high content of sulphur form sulphur dioxide, which is very injurious to crucibles. Such fuels, therefore, should be avoided.

Crucibles will last much longer if the metal is poured as soon as possible after the proper temperature has been reached so that they will not be subjected to the burning action of the flame any longer than is needful. The life of crucibles continually kept at high temperatures is comparatively short. It is of advantage, therefore, to use a crucible first in melting alloys requiring high melting points, then, as it grows older, prolong its life by melting alloys requiring a lower melting point. It is necessary, of course, to clean out any alloy of one kind thoroughly before using the crucible for another alloy, in order to prevent hybrid mixtures. No matter what melting points are used or what alloys are melted, care must be taken in charging the pot not to crowd it full of scrap or heavy ingots of metal, as the expansion of these in melting is sometimes sufficient to crack or otherwise shorten the life of the vessel.

Crucibles will have longer life in round furnaces than in square ones, because the heating is more uniform in the former. For this reason tilting furnaces are easier on crucibles than pit furnaces. In using a pit furnace the life of a crucible is prolonged by placing it in the furnace to cool gradually with the fur-

nace rather than to let it cool in other atmosphere and under various conditions.

A protective paint or a wash made of pulverized carborundum fire-sand mixed with water glass or boric acid, has a resisting effect and prolongs the life of a crucible to some extent. A coating of this kind has been used sucessfully in Europe and has recently been put on the American market.

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